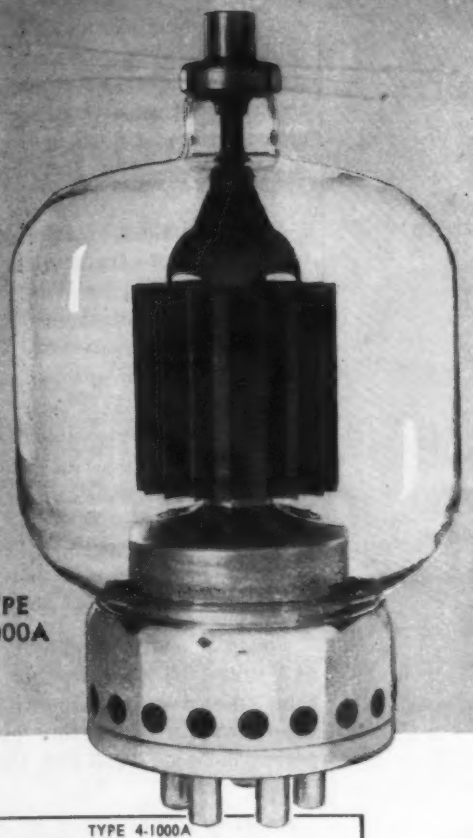
COMMUNICATIONS · BROADCAST AM & FM · INDUSTRIAL · AUDIO



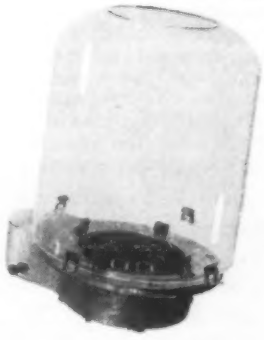
TYPE 4-1000A

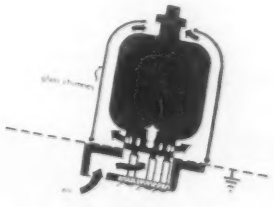
OUTPUT 3 Kw. WITH 14 WATTS DRIVE

Workhorse for communications and industry, the recently announced type 4-1000A is presently the largest of Eimac radiation cooled power tetrodes. High power-gain capabilities, on the order of 230 times, fit the tube to applications requiring high power output with low driving power needs.

The tube has been ruggedly designed to withstand the abuse of the most severe application and abnormal overload. Eimac "know how" of vacuum tube design provides long life expectancy and overall economy of operation. Virtual isolation of the input and output circuits has been achieved, simplifying associated circuit design. Short, low-inductance leads, Eimac's non-emitting grids, and rugged plate impart a high degree of operational stability. High efficiency may be maintained well into the vhf, above 110-Mc. As an example, two tubes operating well within ratings, have provided 5 kw useful output power at 110-Mc.

As a functional accessory, a unique socket design to assist in adequate cooling is available. Illustrated below is the complete unit and a diagram indicating the control of air-flow past the terminals, base seals, around the envelope and to the plate seal. The pyrex glass chimney is included with each socket.





TYPE 4-1000A
ELECTRICAL CHARACTERISTICS

Filament: Thoriated tungsten	
Voltage	7.5 volts
Current	21 amperes
Grid-Screen Amplification Factor (Average)	7.2
Direct Interelectrode Capacitances (Average)	
Grid-Plate (without shielding, base grounded)	0.24 μμfd
Input	27.2 μμfd
Output	7.6 μμfd
Transconductance (i_b = 300 ma., E_b = 2500 v., E_{c_2} = 500 v.)	10,000 μmhos

RADIO FREQUENCY POWER AMPLIFIER AND OSCILLATOR
Class-C Telegraphy
(Key-down conditions, per tube)

MAXIMUM RATINGS	
D-C Plate Voltage	6000 Max. Volts
D-C Screen Voltage	1000 Max. Volts
D-C Grid Voltage	—500 Max. Volts
D-C Plate Current	700 Max. ma
Plate Dissipation	1000 Max. Watts
Screen Dissipation	75 Max. Watts
Grid Dissipation	25 Max. Watts

TYPICAL OPERATION (Frequencies below 40 Mc.)	
D-C Plate Voltage	6000 Volts
D-C Screen Voltage	500 Volts
D-C Grid Voltage	—200 Volts
D-C Plate Current	681 ma
D-C Screen Current	141 ma
D-C Grid Current	41 ma
Screen Dissipation	71 Watts
Grid Dissipation	6.1 Watts
Peak R-F Grid Input Voltage (approx.)	348 Volts
Driving Power (approx.)	14.3 Watts
Plate Power Input	4086 Watts
Plate Dissipation	746 Watts
Plate Power Output	3340 Watts

Follow the Leaders to
Eimac TUBES
The Power for R-F

Export Agents: Frazar & Hansen, 301 Clay Street, San Francisco, 11, California

EITEL-McCULLOUGH, Inc., 185 San Mateo Avenue, San Bruno, California

Introducing packaged VHF Crystal Control by Bliley

Design engineers recognize that peak frequency precision depends greatly on close correlation between crystals and their associated oscillator circuits. In the region above 20 mc it is equally true that circuit design can make a significant difference in drive secured from the oscillator stage. Complete uniformity of construction and careful control of component tolerances assumes extreme importance.

Bliley is now prepared to design and build packaged oscillators for precision VHF applications between 20 mc and 200 mc. Consistent performance of overtone crystals and maintenance of operating tolerances to ±.005% or better over wide temperature ranges is assured by consideration of all significant factors in a package of this kind. The result is a precise frequency source that has sufficient power to meet design ratings.

One possible form of packaged oscillator is shown in the picture. Space requirements in the equipment will determine whether a subchassis or plug-in unit is most desirable. Bliley, with over fifteen years experience in frequency control applications, is exceptionally qualified to assume responsibility for the complete frequency package from conception to delivery.

+ + +

This custom-service is limited, at present, to applications involving production quantities. Inquiries, giving detailed performance specifications, are invited.

Bliley CRYSTALS

BLILEY ELECTRIC COMPANY UNION STATION BUILDING • ERIE, PENNSYLVANIA

are well enough financed to pay the bills until revenue from sponsored programs takes up the load and (2) that the chance of commercial success is twice as good in towns having no competitive station.

Size And Cost of average existing broadcast transmitter buildings, determined by Western Electric in a 610-station survey, is as follows:

POWER (watts)	SERVICE	TYPE*	SIZE (cu ft)	COST
250	a-m or f-m	tr	5,300	$3,700
250	a-m or f-m	tr and stu	19,100	13,200
1,000	a-m or f-m	tr	7,200	6,600
1,000	a-m or f-m	tr and stu	21,000	15,300
3,000	f-m	tr	17,600	10,700
3,000	f-m	tr and stu	30,500	36,500
5,000	a-m	tr	20,600	17,000
10,000	f-m	tr	30,800	22,700
10,000	f-m	tr and stu	51,000	46,300
50,000	a-m	tr	57,600	40,300
50,000	f-m	tr	39,100	43,200

* tr — transmitter building only. tr and stu — combination transmitter building and studios.

Today's construction costs would, of course, be considerably higher than the averages shown, since these cover construction over the period between 1930 and 1947.

Rooftop Rents asked by owners of tall buildings are a matter of concern to many prospective operators of vhf and uhf transmitters. The concern is particularly acute among people who wish to operate point-to-point communications, common-carrier, and relay services which must necessarily function at low cost.

Realtors would do well to carefully study space and facility requirements before quoting. Services such as those mentioned frequently require just a small corner for equipment, need little power and service, can often utilize existing structures for antenna support, and generally leave the lion's share of the rooftop available for f-m and television broadcast station rental.

Technical Dictation throws inexperienced stenographers for a loss. One of the boys on the editorial staff of ELECTRONICS was momentarily puzzled the other day by a letter dealing with *steam* power tubes.

We hear that a mid-western manufacturer is perfecting a protective system for large industrial plants. Watchmen carry con-

cealed radio transmitters operating around 150 mc. When trouble is encountered the transmitters go into action, a neon lamp on the panel of a centrally located receiver flashes a warning and the watchman's code number is indicated by a tape recorder.

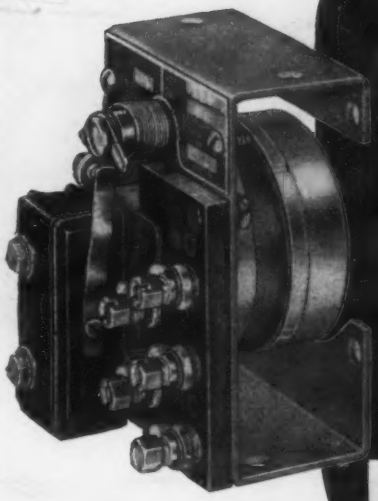
"Radio Tube Design is largely a matter of compromise," says Hytron's Vin Ulrich. "The manufacturer who hits upon the most satisfactory combination of compromises is the one who has the most widely accepted tube types for given applications."

Small Boat Owners tune from one a-m broadcast station to another, hoping against hope that something resembling a complete weather forecast will be appended to news programs. Stations located near water could make a lot of friends by more regularly including wind direction and velocity.

Coast Guard stations operating near 2,600 kc transmit weather forecasts two or three times a day but hesitate to increase the frequency of this service because dissemination of such information is officially the business of the Weather Bureau. Many yachtsmen wish the matter of appropriations could be arranged to permit closer cooperation between the two government agencies. More power and personnel for Coast Guard stations would also pay dividends in safety at sea.

Step In Right Direction is General Instrument's recently inaugurated $500,000 research and engineering program designed to reduce the cost of major components used by television receiver manufacturers.

Unnoticed by most of the men who attended the recent NAB convention at Atlantic City, the aircraft beacon on top of one of the several antenna towers on display in the exhibit hall put out not only conventional flashes but also an occasional group of most unconventional code words. It seems that the boys running the exhibit got a little bored, rigged up an extra set of cams and switched them in when things began to pall.



WARD LEONARD calls on HAYDON for Dependability

in TIME DELAY RELAYS

Ward Leonard is one of many reputable manufacturers of fine quality timers, time delay relays and electrical control apparatus, who depend upon the versatility and adaptability of the Haydon synchronous motors in the design of superior products.

The time delay relay illustrated is designed primarily for such industrial applications as delayed timing for preheating electronic tube filaments before applying voltage and sequence timing in motor controllers. The Haydon 1600 motor provides almost instantaneous self-recycling on breaking the pilot circuit through means of a magnetic shift; choice of standard motor speeds make possible a wide range of adjustable time delay periods and the built-in one-way friction prevents damage to motor on return travel of the cam.

Take time to talk time with Haydon engineers on this and other applications. A fully illustrated Engineering Data Catalog is yours for the asking.

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NOW . . . New Types of ELKONITE* CONTACTS *for Light Duty Applications Like This*

FOR quite a number of years now Elkonite has been *the* standard contact material for heavy-duty circuit interrupting equipment. A Mallory-developed material, Elkonite has been famous for its hardness and electrical conductivity—for its resistance to sticking, to erosion by arcing, to mechanical wear and impact.

Now this same material—fabricated differently and somewhat changed in composition—is available for applications in the light duty field: applications like small relays, mechanical breakers, thermal breakers and similar equipment where silver alloys have heretofore been used.

It has an advantage over silver in that it is less subject to sticking and has a higher hardness. It is superior to most non-silver alloys in its improved finished and uniform contour, which requires no machining. And it is lower in cost than standard Elkonite—available in smaller sizes, too. On the other hand, it will not resist extremely heavy arcing, as standard Elkonite will.

If you need a contact material where the maximum physical properties of true Elkonite are not required, yet where silver does not meet the specifications, here is something to investigate. These new grades of Elkonite are available in standard rivets and projection welding blanks—or can be used in special contacts made to your order. Write for more information.

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The only volume of its kind in the world, this Mallory Contact Data Book contains everything you want to know about contact design, construction, application and materials. Free to engineers who write on company letterhead. $2.50 to others.

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MALLORY ELECTRICAL CONTACTS & CONTACT ASSEMBLIES

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CROSS TALK

▶**AIR** . . . Talking to one of our editors recently, Major E. H. Armstrong opined that recent advances in our knowledge of vhf waves have introduced some radical changes in some homely concepts. Time was, according to the Major, when one explained to non-technical friends that radio waves didn't really go through the air. In fact, we used to say, the waves would get there as well or better if the air weren't there. But not so with vhf waves. Refraction of these waves in the air accounts for much of their availability. If the air weren't there, the marginal service of f-m and television stations would cease to exist. Moreover, variations in the state of the air masses cause fading, once thought to be absent from very-short-wave transmission. So the old order changeth. What the Major says is only too true; the art has much to learn about the transmission of uhf and vhf waves. Much already known has not been passed out widely enough. We can offer some help on this, in the form of a bang-up manuscript by Don Kerr of the Radiation Lab, just ready to toss on the griddle. Watch for it.

▶**VOICE** . . . At the recent NAB convention, a manufacturer of a limiting amplifier, advertising to the delegates, elected to speak in their language. "Our limiter," runs the ad, "gives your station a steady, loud voice!" That's the word for too many broadcast stations today: a steady, loud voice. The broadcasters code, which would limit commercial announcements to three minutes per 15 minute period, ran into heavy weather at the convention, but was finally adopted over the protests of the smaller stations. If followed, this code will do much to combat the growing public resistance to steady, loud voices on the air.

▶**MORE PRIVILEGE** . . . In these columns last July we objected to a rider charge, amounting to $1.26 per month, assessed on owners of television sets in Norwich, Connecticut. Since Norwich is well outside the range of existing television stations, that threat to progress was academic. But the disease spreads. Now comes word from the Wallingford, Connecticut, municipal plant, inside the range of New York stations, that owners of television sets connected to this system must pay $2.50 for the first five kilowatt-hours they buy each month. This is roughly $2.00 extra per month, or 24 dollars a year, over and above what would be charged for the same juice if the television set were absent. This rate increase is based on the same recommendations, and subject to the same objections, as the Norwich case to which we have previously alluded with some feeing.

We are happy to note that the Radio Manufacturers Association, prompted by our outburst, has dug into the facts, intending to combat the forces of evil. The power consumptions and power factors of 15 models of television sets made by eight manufacturers have been listed. The power consumption ranges from 215 to 550 watts, with 328 watts as average. The power factor ranges from 89 to 95 percent, with 92.5 percent as average. The power factor figures are particularly interesting and show that the public utility does *not* have to install large capacity for wattless current. Moreover, the Wallingford company informs us that the peak load on their system occurs between 11 and 12 in the morning, during the spring and summer months from April to October. In the winter, from October to April, it occurs from 4 to 6 in the evening. These hours do not coincide with hours of television programs, except possibly from 4 to 5 pm in winter.

Why then, must owners of television sets pay 24 dollars a year, not for electric power, but for the privilege of being connected. This is more than half the national average electricity bill ($42.90 in 1946). It looks powerful fishy to us. Worse, it looks like charging what the traffic would bear. One ray of hope: The Wallingford authorities say they are merely experimenting with this rate, and are in contact with set owners to find out just what additional demand is placed on their system. We are sure that the facts will not support this charge, and we hope the RMA will make good use of its facts.

electronics Sponsors

Announcing a program of research, underwritten by the publishers of ELECTRONICS, to develop equipment and test the potentialities of the Citizens Radio Service. First equipment, a transmitter meeting FCC specifications, is described in this issue

THE EDITORS OF ELECTRONICS are happy to announce a series of articles, beginning in this issue, on equipment specifically developed for the Citizens Radio Service, operating in the band between 460 and 470 megacycles and ultimately intended for use by the general public for private communication. The first item of equipment, a four-tube crystal-controlled f-m transmitter, is described on pages 84 to 89. Succeeding issues will describe a high-sensitivity f-m superheterodyne receiver, a power amplifier for the transmitter, high-gain non-directional antennas, and will relate the results of comprehensive tests of this equipment in the field.

Walter Hollis, who designed Citizens Radio Service equipment for ELECTRONICS, testing transmitter at Boonton

The Citizens Radio project, the costs of which have been underwritten by McGraw-Hill as a service to the industry, is intended to reveal the potentialities of the new band for public use and to offer equipment designs suitable for production by individuals or commercial organizations. This program, which marks a new departure in technical publishing practice, was undertaken by the editors of ELECTRONICS early in 1947 after discussions with Commissioner Ewell K. Jett, sponsor of the Citizens Radio Service in the FCC.

Citizens Service Slow to Start

The 460 to 470-mc band was first proposed by the FCC before the end of the war, in May 1945, and was made an official part of the allocation table in June 1946. When the band was first announced, engineering opinion on it was generally pessimistic. While all agreed with the basic philosophy of providing a band for the general public, most observers doubted the wisdom of choosing a frequency band as high as 460 to 470-mc for the purpose. But since lower frequencies were already occupied by existing services of higher priority, the allocation stood as originally proposed. In the intervening two and one half years no equipment has been made available commercially for this band.

The reason for the inactivity was not lack of interest, since a sizable

Citizens Radio Project

Commissioner Jett Hopes ELECTRONICS Project Will Speed Citizens Radio

Shortly before the end of the war, the Federal Communications Commission announced a proposed allocation of the band 460-470 megacycles for a citizens radio service. Intended for use by the general public for private or personal communication, the new band is available to any citizen who agrees to abide by the law, with no technical license requirements. To serve such a purpose, equipment for the new band would have to be simple and virtually foolproof. In June, 1947, the Commission issued tentative specifications for the equipment and announced a plan for type approval which will assure the adequacy of the equipment before it is offered to the public.

The proposal has received widespread approval in the industry. But engineers have found it difficult to design equipment for the band which would meet the necessary specifications, particularly with respect to frequency stability. It has appeared that some time might elapse before the citizens radio service would become a practical reality.

It is, therefore, most reassuring to know that the Editors of ELECTRONICS have underwritten a comprehensive program to develop and test equipment for this important new service. It is my sincere hope that this program, in which the industry is invited to participate, will reveal the full potentialities of the new service and that the public will be able to make full use of the facilities in the near future. It is to be emphasized that type approval by the FCC will be necessary before large-scale production of any particular design of equipment begins.

(signed) **E. K. JETT**
Commissioner
Federal Communications Commission

market for such equipment has been predicted by equipment manufacturers from the very start. The reason was rather a difficult technical problem. Stated briefly, engineers found it next to impossible to generate adequate amounts of power at the 460 to 470-mc frequency with equipment simple enough, and foolproof enough, to serve the non-technical public in portable and mobile service.

It was feared by many that interference would prove, even within a 10-megacycle band, insuperable if radiating receivers and non-stable transmitters were used in any number in heavily populated areas. Secondly, the industry has been unwilling to offer equipment for the Citizens Service until more was known about its adequacy for different uses. The 460 to 470-mc band has quasi-optical properties under normal conditions, so communication might prove impossible unless line-of-sight paths were maintained between units. While such a restriction might prove acceptable on farms in the Plains States, it would certainly prove a hindrance in built-up cities, suburbs, and in rolling or mountainous country.

Survey Conducted by Editors

A survey conducted by the editors in 1946, among manufacturers known to be interested in the Citizens Service, revealed practically no activity beyond laboratory measurements on self-excited and superregenerative units, all of which seemed inadequate. It looked as though the new service might go begging. Shortly thereafter the staff of ELECTRONICS resolved to set up a development project, to see whether technical and operational answers to the unsolved problems might be found. Encouraged by Commissioner Jett to proceed, the following plan was put in action:

An appropriation of funds was set up to underwrite the costs of parts and materials, engineers' and technicians' time, and application for an experimental license was made to the FCC. A search was then instituted to find a project engineer familiar with the problems of stable transmitters and receivers at these frequencies, who would be willing to undertake the project on his own time. This search was rewarded in the person of Walter C. Hollis, an engineer on the staff of the Sperry Gyroscope Company. Mr. Hollis, who has published an article in ELECTRONICS

on the design of tuned-line resonators suitable for this band, agreed to design and supervise the construction of suitable equipment.

Sperry was not involved in the project but was asked whether there was any objection to Mr. Hollis undertaking the assignment, provided all activity was confined to out-of-office hours, and graciously gave assent. The equipment is, accordingly, a personal development of Mr. Hollis. All rights in the design have been relinquished by him, as well as by the publishers of ELECTRONICS, and are hereby placed in the public domain. Any person or organization who desires to copy the designs or equipment may do so for any private or commercial purpose.*

When the project was well underway, the FCC announced tentative equipment specifications which would have to be met before type approval would be given to equipment or transmitting licenses issued. These specifications did much to remove the atmosphere of uncertainty surrounding the engineering problem. On May 20th, the FCC issued an experimental station construction permit, under the call W2XSN, to the McGraw-Hill Publishing Company to cover the development and testing of the equipment.

By mid-September the initial item of equipment, the transmitter previously mentioned, had been completed and subject to an equipment test in the field, where it performed satisfactorily, as outlined in later paragraphs. Accordingly, the editors were encouraged to announce the program and proceed with publication of technical details.

Purpose of Program

In announcing the program, the editors wish to emphasize that its purpose is developmental and experimental. Many (in fact, most) of the questions concerning the Citizens Service remain unanswered at this stage, particularly those relating to performance of the equipment in the field. Within the limits of its resources, the staff intends to test the system and to report the results objectively, good or bad, in coming issues. But the full potentialities of the service can be recognized only after an extensive test, conducted by many groups in different parts of the country and under different conditions.

To make possible the widest use of the designs, a primary objective of the program has been to use standard and conventional components throughout, and to eliminate entirely the need for specially machined cavities and other difficult-to-construct items. Cost figures will be published as the program proceeds. At the moment it appears that the investment in parts and materials, for a complete 465-mc crystal-controlled transmitter-receiver (without power amplifier) including power supply will be under one hundred dollars at current net prices.

Although the aim has been simplicity and inexpensive construction, the equipment has been required to meet the more strict of the two proposed FCC frequency tolerances and to meet standards of good engineering practice throughout.

FCC Specifications

Since the equipment under development was designed to meet FCC regulations, it is pertinent to state the proposed FCC specifications In accordance with FCC Public Notice 8387, issued June 27, 1947, it is proposed to divide the citizens band into three regions. The central region extends from 462 to 468 mc, within which any approved equipment may be used, including equipment of poor frequency stability (Class B stations, ± 0.4 per cent). The other two regions are the band edges from 460-462 mc and 468-470 mc, within which only equipment having excellent frequency stability (Class A stations, 0.02 percent) may be used. The 460 to 462-mc region is restricted to equipment operating at fixed locations; the other regions are for fixed, mobile, or portable operation.

Modulation may be of the amplitude, phase, or frequency type, and all sidebands are to be confined within a 200-kc band. Transmission may be by c-w radiotelegraphy, radiotelephone, or facsimile. The input plate power to the final stage must be limited to 50 watts in the band-edge regions and 10 watts in the central region. Spurious radiations from the transmitter must be eliminated or reduced in accordance with good engineering practice, and in any event shall not cause interference to receivers of good engineering design tuned outside the 460 to 470-mc band.

When a manufacturer intends to produce 100 or more units of a given type, he may submit a typical production equipment to the FCC for type-approval tests. If the equipment meets FCC requirements it will be awarded a type-approval certificate and thereafter transmitting licenses may be issued to applicants owning such equipments. If less than 100 units are to be manufactured, type-approval tests will not normally be conducted but full information on the unit may be forwarded to the Commission which may, at its discretion, decide to test a sample in accordance with the standard type tests.

Choice of Basic Design

In developing the ELECTRONICS Citizens Radio equipment, it was decided to construct initially an equipment which would meet the Class A specifications, that is, 0.02 percent frequency tolerance. This choice was dictated by two factors: first, such equipment can be used for any purpose, anywhere in the band; second, the specifications could be met by a straightforward engineering approach using crystal control, whereas the Class B design might require an extensive investigation into non-crystal-controlled stable oscillators. As the program proceeds, it is hoped that a suitable Class B design, consuming the minimum amount of space, weight, and power, and taking advantage of the 0.4 percent frequency tolerance, will be evolved.

Since the 0.02 percent tolerance virtually demands crystal control, it was decided to produce the simplest possible crystal-controlled transmitter, using conventional miniature tubes, tuned circuits, and simple square cavities. All metal-working would be confined to that

* Commercial organizations are reminded that licenses under various patents covering the use of vacuum tubes and circuits are required before any transmitting or receiving equipment embracing these patents may be offered for sale. Most equipment manufacturers hold licenses for this purpose. Others are advised to secure licenses before proceeding.

possible with a drill press (or, in a pinch, a portable electric drill), an ordinary vise, and usual small tools. The estimate of primary power required was 50 watts, so it was decided to build the equipment for mobile use in vehicles having a six-volt storage battery, or for fixed station operation.

The r-f power-output specification was broken down into three categories. The initial transmitter would have a power output less than one watt (the actual unit produced one-quarter watt at carrier frequency, as measured by a Bird wattmeter) and would be suitable for short-range operation. A power amplifier, employing standard components, would increase the power output to about 3 watts. A more complicated power amplifier, employing a lighthouse tube and requiring some skill in machining cavities, would permit operation at the maximum permissible level of 50 watts input to the final stage.

Frequency modulation (actually phase modulation plus frequency multiplication) was decided upon for the following reasons: A simple phase-modulation network is available which uses a germanium crystal and will provide about 15-kc deviation after multiplication from a 4.3-mc crystal frequency to the 465-mc carrier frequency. This modulation system is simpler and consumes less power and tubes than the corresponding amplitude modulator. The power efficiency of the final stage is higher when f-m is used. Finally, the signal-to-noise performance of the system as a whole, and consequently the range of coverage, is superior on f-m provided a high modulation-index is used and the receiver is built for high sensitivity. Both of the latter requirements are met in the design.

Basic Transmitter

The first equipment, the basic transmitter described in detail in the following pages, follows the plan just outlined in all respects. It employs but four tubes, produces a crystal-controlled carrier at 465 mc with 0.25-watt output power. All the tubes are standard miniature types mounted in standard sockets. Ordinary tuned circuits are used up to the final stage, at which point two resonators, (actually loaded sections of coaxial line, built in square shape) are introduced. A frequency multiplication of 108 times is achieved in three tubes, two of which are double triodes.

The transmitter is designed as one of three units of similar size, all of which will be mounted in a single container in the completed transmitter-receiver. The other two units are receiver, and power-supply control-switching unit.

Equipment Test

The basic transmitter was subjected to a test in the field at Boonton, N. J., on September 10, 1947. The assistance of Jerry Minter of the Measurements Corporation, in measuring the field strengths and providing test facilities, is much appreciated. In the test, two quarter-wave ground-plane vertical antennas were used, one mounted on the top of an automobile, the other placed on the laboratory roof at an elevation of 15 feet. The transmitter was operated from the car. The transmitter power supply, a vibrator power pack, was supplied from the car battery at 6.4 volts and produced 135 volts on the plates of the tubes. A carbon-button microphone and microphone amplifier, mounted on the power supply chassis, fed audio voltage at 5 volts level to the phase-modulation network of the transmitter proper. The transmitter was placed on the front seat of the car. During six hours of testing, including driving over rough country roads, the transmitter remained in adjustment and gave no trouble whatever.

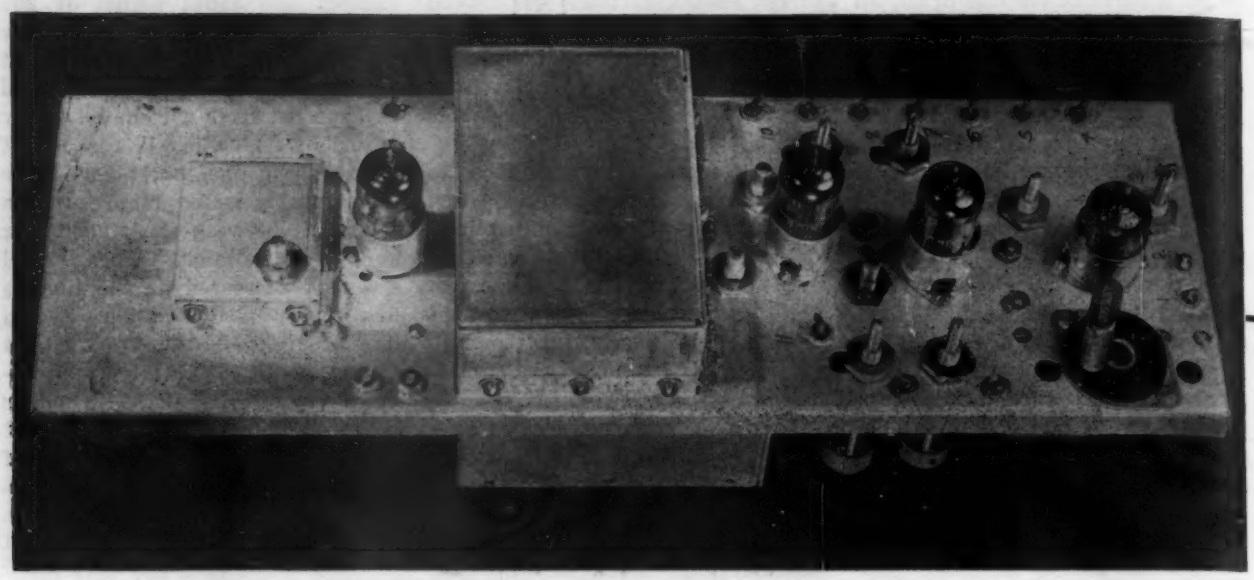
To measure field strengths, an AN/APR-4 search receiver with self-contained signal-strength meter was employed. This produced a 30-mc carrier (the intermediate frequency) which was detected by a Hallicrafters model S-27 f-m/a-m receiver and fed to a loudspeaker. The input signal to the APR-4 receiver (picked up by the ground-plane antenna on the roof) was compared by the substitution method with the output from a Measurements Corporation model 84 uhf signal generator. A matching stub was used to secure a proper match to the antenna.

The following results were obtained: An input signal of 200 microvolts was developed when the transmitter antenna was located at 25 feet. This is lower than would be expected from a radiated power of 0.25 watt, which is the output measured in the laboratory. The loss probably is accounted for by a mismatch between the transmitter and its radiator. The signal strength decreased as the inverse first power of the distance (when line of sight prevailed) out to a distance of 1600 feet (approximately one-third mile.) No longer line-of-sight path was available at this location. Complete quieting of the receiver occurred, with consequent full intelligibility of the speech modulation at a receiver input of 8 microvolts, and bare intelligibility was achieved with 4 microvolts input.

Although this test was not intended to show any propagation effects, some incidental observations were made which indicate factors to be studied at length when propagation tests are begun. It was found that foliage produced a pronounced shielding effect, so much so in fact that communication could not be maintained beyond one-half mile since heavy foliage intervened along the roads available at the Boonton location. In one quantitative test of this effect, it was found that a single row of small birch and poplar trees about 50 feet from the transmitter, then located 1500 feet from the receiver, introduced an attenuation of two-to-one in voltage.

The tests revealed that the transmitter would survive rough usage without loss of adjustment, and showed that in-the-clear transmission paths up to one-third mile could be covered adequately with the equipment putting out substantially less than its full output. However, even with a properly matched antenna, it was clear that higher power (available from the power amplifier scheduled for test in the near future) would be required for full coverage at greater distances, particularly if obstructions and foliage intervened. These matters will be investigated in tests to be conducted in future weeks. —D.G.F.

(1) Walter C. Hollis, Design of Transmission Line Tank Circuits, ELECTRONICS, p 130, May 1947.



Top view of transmitter. Output of 4.3-mc crystal (lower right) is multiplied 108 times in three tubes to 465 mc. Final stage, a 6J4 triode (left), produces one-quarter watt output

TRANSMITTER for the Citizens Radio Service

Simple low-power f-m unit, using conventional tubes and components, meets FCC Class-A specifications for 460 to 470-mc band. Phase modulation and crystal control produce stable quarter-watt output in unit designed as part of portable-mobile equipment for general public

THE equipment described in this article was constructed as part of the ELECTRONICS Citizens Radio Project. The purpose of this project, as well as the philosophy underlying the design of the equipment and results of initial tests, are stated elsewhere in this issue (p 80). The present treatment is intended to provide sufficient discussion of the electrical and mechanical details of the transmitter to permit its construction and adjustment by those readers who may wish to copy it for their own use.

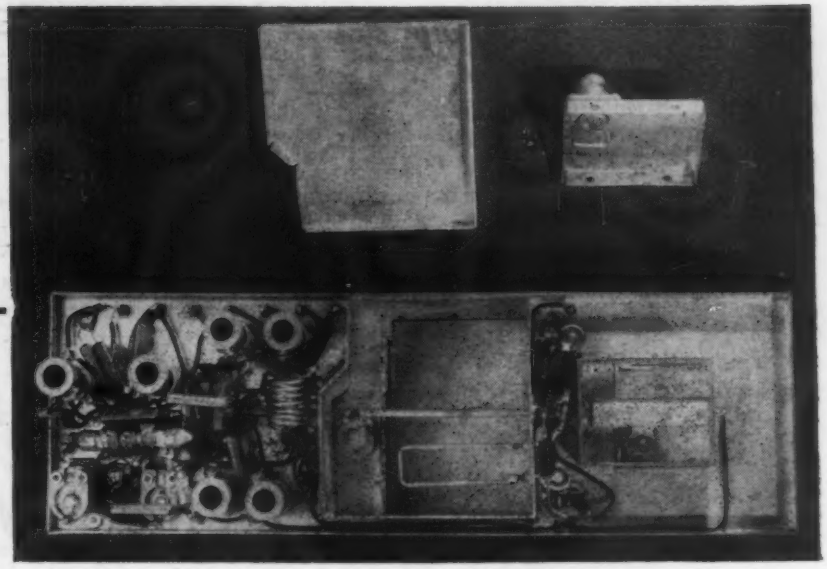
The transmitter is a direct crystal-controlled unit employing four tubes and a phase-modulation network. The power output of the final stage is one-quarter watt at the center frequency of the citizens band, 465 mc. This power level is small, and is admittedly not sufficient to permit full utilization of the citizens band when obstructions intervene in the transmission path. However, a surprisingly large range can be covered in direct line-of-sight with this power output. A line-of-sight path of 25 miles (transmitting and receiving antennas elevated 100 feet or higher) can be covered with a power output of only 11.5 milliwatts, using dipole antennas, with a receiver noise figure of 10 db and a carrier-to-noise ratio of 10 db. This computation is based on the well known relation which gives the attenuation between half-wave dipole antennas in free space:

$$\text{Attenuation} = 10 \log_{10} \frac{64\pi^2 r^2}{9\lambda^2} \text{ db} \qquad (1)$$

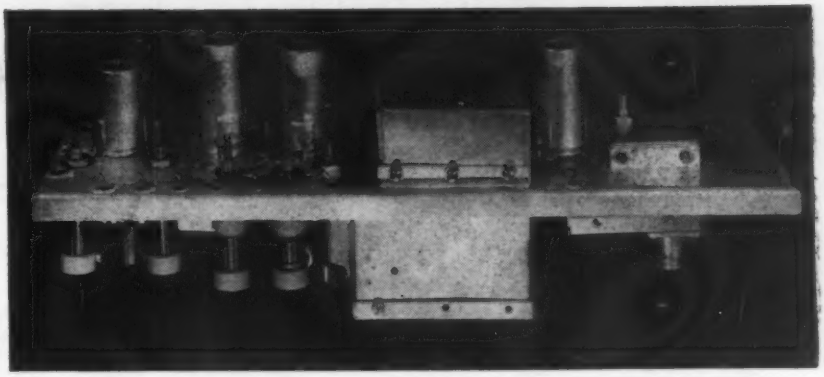
where the distance r between transmitter and receiver and the wavelength λ are in the same units, e.g. meters. It is expected (although tests have not yet been completed at maximum range) that the transmitter described will cover a 25-mile line-of-sight path with 20-db carrier-to-noise ratio.

The phase modulation network,

By
WALTER C. HOLLIS
*Radio Engineer, Sperry Gyroscope Company**



Bottom view, showing interior of resonators and coupling loops. Conventional coils are used up to 116 mc



Side view, showing enclosed quarter-wave-line resonators at input and output of final stage

Part I

of a Series

described later in this article, is designed to produce a maximum modulation of 28.6 degrees (one half radian). At the lowest modulating frequency in the voice band (300 cps) this phase deviation will produce a frequency deviation of approximately 16 kc when a frequency multiplication of 108 times is introduced between modulator and carrier output. This deviation compares favorably, in its ability to reduce noise, with the 75-kc deviation employed in f-m broadcasting provided the maximum modulating (voice) frequency is restricted to 3,000 cps. The deviation produces sidebands which are well within the 200-kc channel width specified by the FCC regulations.

Circuit Description

As shown in the block diagram of Fig. 1, the transmitter employs a 6AK5 crystal-controlled oscillator, a 1N34 germanium crystal diode in the modulation network, a 6J6 twin tripler, a 6J6 tripler-doubler, and has a 6J4 doubler in the final stage.

The oscillator employs the screen as the plate of a conventional tgtp. oscillator. The output of this crystal-controlled oscillator is electron coupled through the plate to the phase modulating network. The phase modulating network is a constant-impedance network, the phase of which is varied through audio modulation on the crystal diode.

The phase-modulated carrier of 4,305.560 kc drives one unit of the first 6J6 tube as a tripler. The tripled output then feeds the other unit of this same 6J6 as another tripler. The output of the first 6J6 is thus nine times the crystal frequency, or 38.75 mc.

One unit of the second 6J6 is driven as a tripler whose output

* The equipment described was produced by Mr. Hollis as an independent consultant to the McGraw-Hill Publishing Company. For a full account of ELECTRONICS Citizens Radio Project, see p 80.

feeds the other unit of the same 6J6 as a doubler. The output of the second 6J6 is fifty-four times the crystal frequency, or 232.5 mc. All sections of the 6J6 are conventional grid-driven harmonic generators. The output stage of the transmitter is a 6J4 employed as a grounded-grid doubler, the output feeds the antenna through a coaxial cable.

Circuit Details

The complete schematic diagram of the 465-mc transmitter is shown in Fig. 2. Values of all component parts are indicated. A 6AK5, V_1, is used as the oscillator-buffer. The screen, grid, and cathode are used as a triode in the conventional oscillator. Y_2 is a quartz crystal which, together with C_2, determines the frequency of oscillation. C_2 is used for fine frequency adjustment. R_1 in series with R_2 provide grid bias through grid rectification. In addition, R_2 is bypassed for r-f by C_3 and is used as a metering resistor for oscillator grid current. L_1 is a permeability-tuned coil which, together with C_4 and screen-to-cathode tube capacitance, forms the screen resonant circuit. R_4 drops the voltage supplied to the screen of the 6AK5 tube and, with C_5, forms a decoupling filter.

The output is coupled through the plate. Output voltage for driving the first tripler is developed across the modulating network to be described later. L_2 is a permeability-tuned coil which, with C_6, the output capacitance of the oscillator and the input capacitance of the first tripler, constitutes the plate resonant circuit. R_3 is a dropping resistor which places the plate voltage below the screen by a sufficient amount to reduce output voltage to the level required by the modulating network. R_3 and C_7 form the plate decoupling filter. C_8 and C_{11} are blocking capacitors. R_5 and R_6 develop the necessary grid bias for the first tripler through grid rectification. R_6 bypassed by C_{12} serves as a grid metering resistor for the first tripler.

Components Y_1 and C_1 are the frequency control and frequency

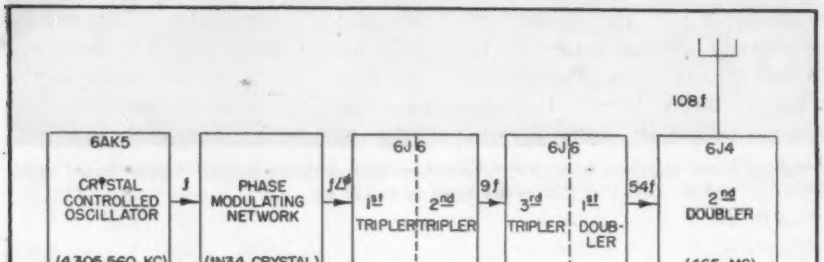
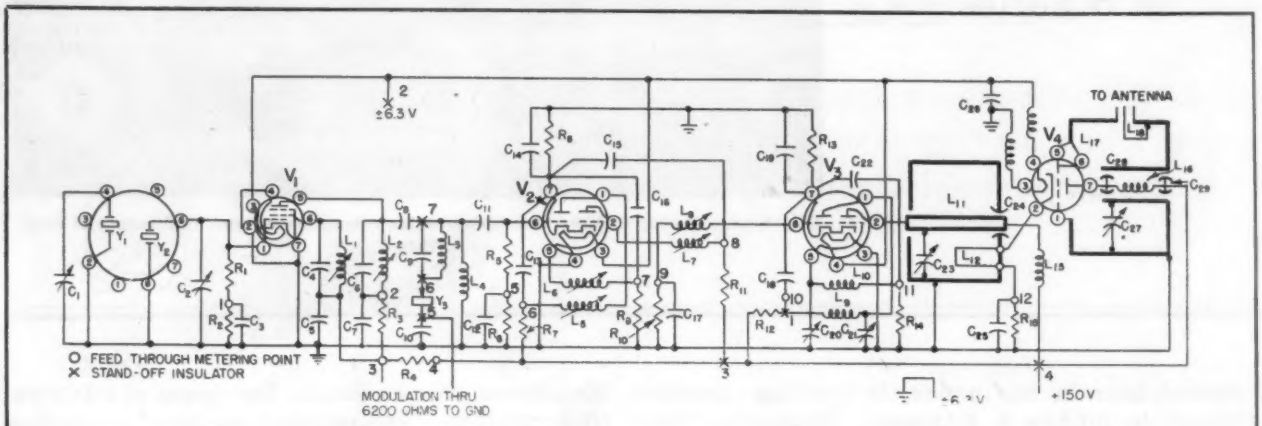


FIG. 1—Block diagram of transmitter. Tubes are conserved by operating three 6J6 triode sections as triplers. Phase modulation network produces 25-kc deviation



C_1, C_2—Erie Ceramicon TS2A trimmer, 7 to 45 $\mu\mu$f
C_3, C_8, C_{10}, C_{11}, C_{15}, C_{17}—350 $\mu\mu$f silvered mica
C_4, C_6—56 $\mu\mu$f silvered mica
C_5, C_7, C_{12}, C_{13}, C_{14}, C_{16}—700 $\mu\mu$f silvered mica
C_9—Erie insulated Ceramicon, 12 $\mu\mu$f
C_{18}, C_{22}—70 $\mu\mu$f silvered mica
C_{19}, C_{25}, C_{26}—Erie 370FA button mica, 235 $\mu\mu$f
C_{20}, C_{21}, C_{23}, C_{27}—see text

C_{24}—Erie 470BH button mica, 1,000 $\mu\mu$f
C_{28}, C_{29}—Erie 370BB button mica, 1,000 $\mu\mu$f

L_1, L_2—see text
L_3—r-f choke, 1 mh
L_4 to L_{18}—see text

R_1—Allen-Bradley, 250,000, $\frac{1}{2}$ w
R_2, R_6—Allen-Bradley, 10,000, $\frac{1}{2}$ w
R_3, R_4—Allen-Bradley, 15,000, $\frac{1}{2}$ w
R_5, R_9, R_{10}—Allen-Bradley, 10,000, $\frac{1}{2}$ w
R_7, R_{11}, R_{12}—Allen-Bradley, 1,000, $\frac{1}{2}$ w
R_8, R_{13}—Allen-Bradley, 100, $\frac{1}{2}$ w
R_{14}—Allen-Bradley, 6,800, $\frac{1}{2}$ w
R_{15}—Allen-Bradley, 390, 1 w

V_1—6AK5
V_2, V_3—6J6
V_4—6J4

Y_1—Auxiliary crystal
Y_2—Hunt Corp. CR7, 4,305.560-kc crystal
Y_3—IN34 crystal diode

FIG. 2—Complete schematic of transmitter. Socket orientation and feed-through numbers correspond to mechanical layout of chassis, shown in the drawing at the right

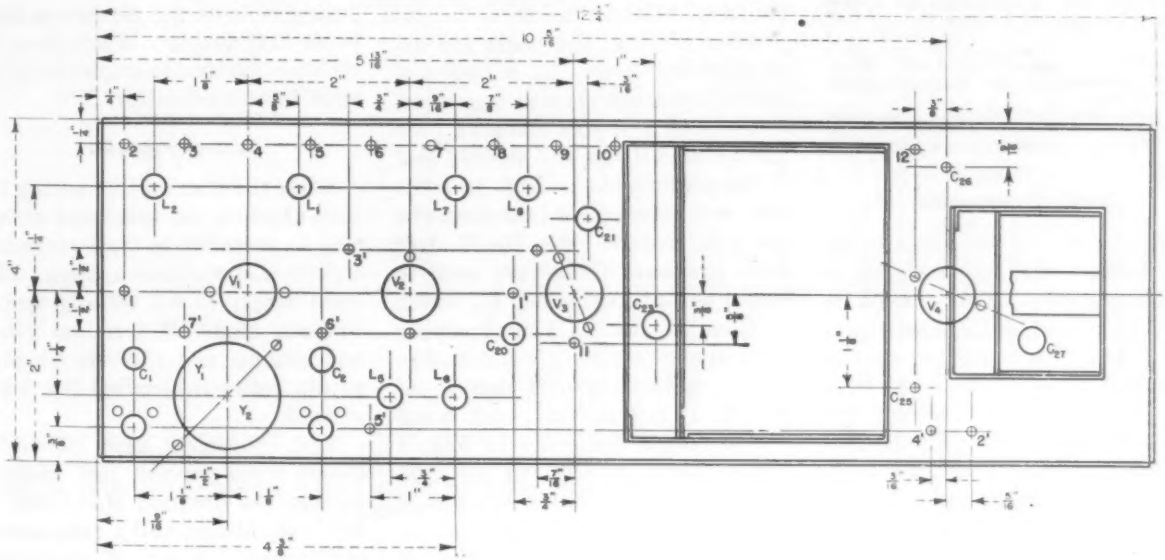
adjusting elements for supplying the local oscillator frequency for the receiver, to be described in a later issue.

The oscillator plate circuit load is the modulating network consisting of C_9, Y_3, L_4, L_5, C_{10}, and a 6,200-ohm resistor in series with a low-impedance modulating source. This network is the same as that used in the Raytheon cascade-phase-shift system[1], with a IN34 crystal (Y_3) replacing the cathode follower. For the network to present a constant impedance, the reactance of L_4 must be twice the reactance of C_9. L_5 presents a high impedance to the oscillator frequency, but provides a low-resistance d-c return for the rectified current of modulating crystal, Y_3. Y_3, in combination with C_{10} and the 6,200-ohm resistor in series with the modulating voltage, presents a variable resistor which is a function of the modulating voltage, in series with C_9. This variation in resistance causes the phase angle of the impedance to vary in accordance with the modulating voltage. As the electron-coupled oscillator output is essentially a constant-current generator, the voltage developed across the modulating network is phase modulated with negligible residual amplitude modulation. This property of negligible residual amplitude modulation is used to tune L_5. The procedure used is discussed under tuning adjustments.

All succeeding multiplier stages, except the final stage, are conventional grid-driven triode harmonic generators, employing the dual triode 6J6. Each stage except the first doubler employs conventional double-tuned circuits. These offer ease of excitation adjustment, freedom from parasitic oscillations, and good harmonic rejection. Grid bias resistors have been chosen for optimum output. Both 6J6 tubes, V_2 and V_3, are protected from overload due to loss of excitation by cathode bias resistors R_8 and R_{13} respectively.

The output tank circuit for the first doubler is unconventional. The tank circuit is a reentrant resonator of the capacitive-loaded transmission-line type[2]. The capacitive loading is a variable capacitor, C_{20}, and the inductive portion L_{11} consists of a length of short-circuited transmission line in a sheet metal shield. The plate supply is bypassed to ground by capacitor C_{24}, and is series fed through filter choke L_{15}, self-resonant at about 230 mc.

The output tube, V_4, is a 6J4 employed as a grounded-grid doubler. The output of the first doubler, at 232.5 mc, is inductively coupled to the cathode of V_4 by means of pickup loop L_{12}. As the driving impedance of a grounded-grid doubler is very low (a few hundred ohms), the circuit is untuned and noncritical. The output tank circuit is another transmission line resonator consisting of a variable capacitor, C_{27}, and a length of short-circuited transmission line, L_{17}. The plate supply is shunt fed through the filter arrangement consisting of C_{28}, L_{16}, and C_{29}. The output to the antenna is coupled through a pickup loop, L_{18}. Grid bias is supplied by the voltage drop through cathode resistor R_{15}, bypassed for r-f by C_{28}. L_{13}, and L_{14}, are self resonant chokes



HOLE SPECS:
Feed-throughs 1 to 12-G drill (2 to 10, Spaced 3/1″)
Stand-offs 1′ to 7′, #30 drill
Coils L1, L2, L5, L6, L7, L8–$\frac{1}{4}$″ drill
Capacitors C1, C2–3/16″ drill spaced 7/8″, #30 drill spaced 7/16″
Capacitors C19, C25, C26–#36 drill
Capacitors C20, C21, C23, C27–$\frac{1}{4}$″ drill
Tube sockets for V1, V2, V3, V4–21/32″ hole, #30 drill spaced 7/8″
Lock-in socket for Y1, Y2–1 5/16″ hole, #30 drill spaced 1 11/16″

FIG. 3—**Mechanical layout of chassis. Slight differences from layout shown in photos have been introduced to simplify construction. Relative location of tube sockets and resonators is critical**

which place the filament at the same r-f potential as the cathode. C_{20} bypasses all filaments to ground.

Parts List

In addition to the parts listed with the circuit diagram, the following are required:

1 lock-in socket
4 miniature tube sockets
6 National XR50 coil forms
4 E. F. Johnson capacitors, type 160-107 (3-15 μμf)
Note: Modify Johnson capacitors C_{20}, C_{21}, C_{23}, and C_{27} to have three stator plates and four rotor plates.
14 glass-sealed feed-throughs (such as Electrical Industries, Inc. type AB-60W-PP)
7 stand-off terminals (such as Winchester Co., stand-off No. 754)
8 1-watt Allen Bradley resistors, 100,000 ohms or larger
1 ½-watt Allen Bradley resistor, 100,000 ohms or larger
1 CIU-UG-58/U panel mounting connector
Miscellaneous hardware, wire, solder, 1/32-inch half-hard sheet brass

At current net prices, total cost of parts is approximately $40.00.

Coil Specifications

L^1, L^2, L^4—41 turns No. 27 heavy formvar wire, close wound on National XR-50 form
L_3—250-microhenry universal-wound r-f choke (commercial tolerances can be compensated by adjustment of C_3)
L^5—50 turns No. 29 heavy formvar wire, close wound on National XR-50 form
L^7—15 turns No. 20 heavy formvar wire, close wound and centered on National XR-50 form
L^8—12 turns No. 20 heavy formvar wire, close wound and centered on National XR-50 form
L^9—4 turns No. 14 tinned copper wire, ½ inch diameter, space wound for 7/16 inch length, self-supported between C_{21} and stand-off No. 1.
L_{10}—3 turns No. 14 tinned copper wire, ½ inch diameter, space wound for ¼ inch length, self supported between C_{20} and feed-through No. 11
L_{12}, L_{14}, L_{15}—15½ turns No. 22 plain enameled, close wound on 1-watt Allen-Bradley resistor, 100,000 ohms or larger, dipped in glyptal
L^{16}—12 turns No. 22 plain enameled, close wound on ½-watt Allen-Bradley resistor, 100,000 ohms or larger, dipped in glyptal

Chassis Construction

The chassis is of conventional sheet metal construction shown in the photographs. The chassis is made entirely of $\frac{1}{32}$ inch half hard sheet brass. The completed chassis consists of a drilled base 12¾ by 4 by $\frac{11}{32}$ inches upon which are mounted two resonators for the final multiplier stages. With the resonators and all parts and tubes in place, the overall height is 4¼ inches. The details given below are slightly different from the photographs. These changes have been made to simplify the construction and do not impair the performance.

The bottom view of the chassis layout is shown in Fig. 3. All holes have been identified with the component indicated on the circuit diagram of Fig. 2. A mounting lip projects $\frac{3}{8}$ inch below the bottom of the chassis on all four sides, as is seen in the sectional elevation view of Fig. 4. Two mounting holes for the resonators are provided in the chassis base. The cutout for the resonator for the first doubler is $2\frac{9}{16}$ x $3\frac{9}{16}$ inches; for the second it is $2\frac{1}{16}$ x $1\frac{9}{16}$ inches. Lips projecting $\frac{3}{8}$ inch above the top of the chassis base are provided for mounting each resonator.

The layouts for the first doubler resonator shield and the second doubler shield are shown in Fig. 5 and 6. After cutting, the shields should be bent as shown in Fig. 3 and 4, and soft soldered along the quarter-inch lips provided in the layouts. The shield for the second doubler resonator should have its center conductor, consisting of ½-inch diameter by $\frac{1}{16}$-inch wall brass tubing, soldered into place as indicated in Fig. 3 and 4. In addition, covers with ¾-inch lips should be made to fit each shield. These may be anchored in place by 4-40 screws tapped into the shields. The cover for the output resonator should be drilled for mounting a UG-58/U r-f fitting for the output connection, as shown in the photographs. All chassis parts should be cadmium plated to resist corrosion.

After plating, the parts are assembled as follows: C_{24}, a 1,000-μμf type 470-BA button mica capacitor, is centered and soft soldered over the ½-inch hole in the shorted end of the first doubler shield. In addition, two glass-sealed feed-throughs are soft soldered into the G drill holes provided. These are used to mount output pickup loop L_{13}, which is made of No. 14 tinned copper wire, approximately 1 x ¾ inch. The center conductor should next be installed. It is made of ⅛-inch brass rod of length indicated in Fig. 4 and threaded on the end for 2-56 nuts. The center conductor should be bolted through C_{24} with a lug provided for mounting L_{15}. The assembly constituting L_{11} and L_{13} is then mounted on the chassis base by means of the mounting lip and 4-40 screws tapped into the shield. The inside junction between the shield and the chassis base should be soldered to provide a solid electrical connection. C_{25} should then be mounted on the chassis and the two stator uprights soldered to the center conductor. This assembly constitutes the complete resonator for the first doubler. The mounting holes for the socket for V_3 are so aligned that terminal No. 2 may be soldered directly to the center conductor of the resonator.

The output resonator is next assembled. C_{26}, L_{16}, and C_{28} are assembled to the center conductor by soldering as indicated in Fig. 4. C_{27} is mounted and the two uprights soldered to the center conductor. The resonator then is mounted on the chassis base by means of the mounting lips and 4-40 screws tapped into the resonator shield. The socket for V_3 is next mounted and terminals 1, 5, and 6 soldered directly to the output resonator.

All feed-through connectors should next be soldered into holes provided in the chassis base. All other components may then be mounted on the chassis base, taking care to align all terminals for shortest connections. C_{26} and C_{27} are mounted such that terminals 5 and 1, respectively, on the tube socket for V_3 may be soldered directly to the terminal lugs provided on the capacitors. L_9 and L_{10} are mounted axially and the spacing adjusted during tune-up for maximum drive to the first doubler. Where possible, series resonance is employed in the mica bypass capacitors.[3]

Tune-up Procedure

After the transmitter wiring has been checked, the tubes and crystal may be installed in their respective sockets and voltages applied. Filament supply at 6.3 volts is applied between stand-off terminal No. 2 and ground, and 150-volt d-c plate supply between terminal No. 4 and ground.

Test equipment used included a 20,000 ohms-per-volt test analyzer such as the Simpson Model 260, an audio oscillator, and a cathode-ray oscilloscope. A set of absorption wavemeters is useful to assure that the proper harmonic is tuned in each stage.

First connect the voltmeter between metering point 1 and ground. Starting with the poly-iron slug of L_1 all the way in, screw out the slug, watching grid current as registered on the voltmeter. Note

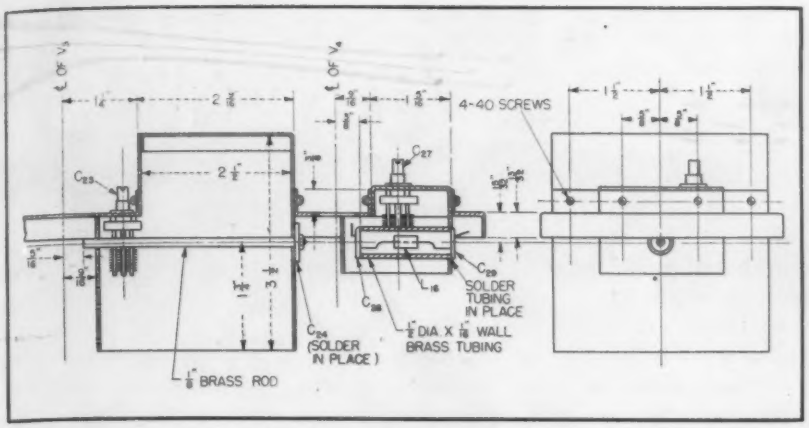


FIG. 4—Side view of chassis, showing constructional details of resonators operating at 232.5 and 465 mc

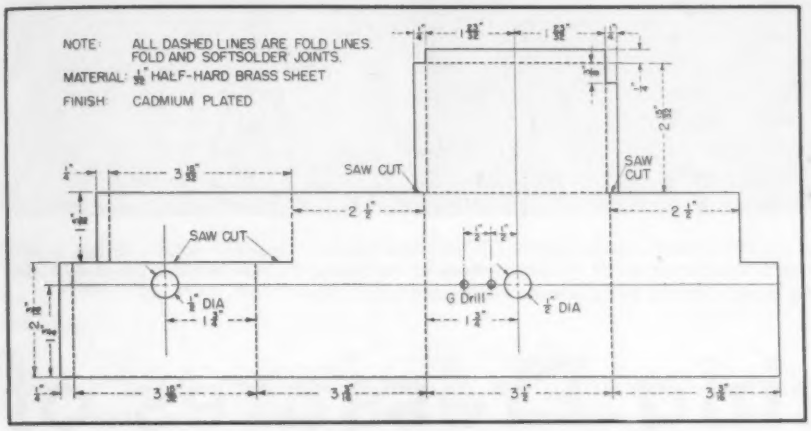


FIG. 5—Shield can for 232.5-mc resonator. Made from brass sheet, this structure can be bent into shape without machining

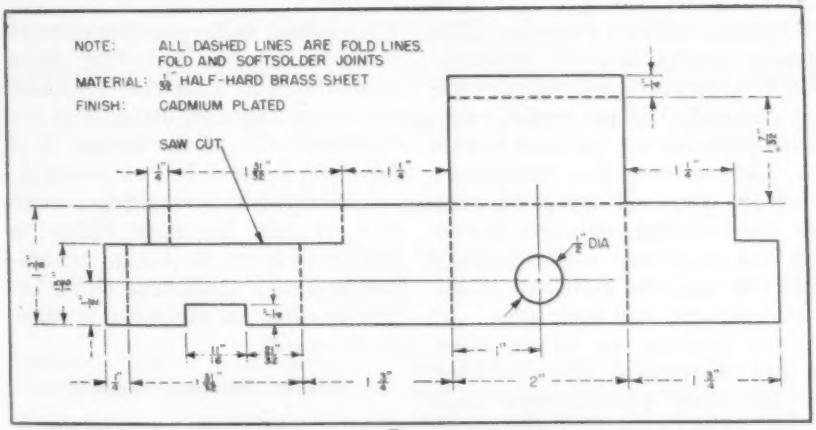

NOTE: ALL DASHED LINES ARE FOLD LINES. FOLD AND SOFTSOLDER JOINTS
MATERIAL: 1/32" HALF-HARD BRASS SHEET
FINISH: CADMIUM PLATED
SAW CUT
½" DIA

FIG. 6—Shield can for 465-mc resonator. If dimensions are followed accurately, both resonators may be tuned over band without mechanical adjustment, by adjusting loading capacitors

maximum reading and back off to about half of the maximum reading.

Next connect the audio oscillator through a 6,200-ohm resistor between stand-off 5 and ground, and set the output to about 5 volts. Connect the vertical amplifier of the cathode-ray oscilloscope between metering point 5 and ground. Through grid rectification in the first tripler, any amplitude modulation occurring in the modulation network appears across R_s and may be seen on the oscilloscope. Adjust L_2 for a null (or minimum) as seen on the oscilloscope. L_2 is now properly adjusted and should *never* be retuned except by this method. The audio oscillator and oscilloscope may now be disconnected and the 6,200-ohm resistor returned to ground.

The voltmeter should now be connected between metering point 7 and ground and L_8 and L_9 adjusted for maximum grid drive as indicated on the voltmeter. The absorption wavemeter should be used to make sure that the proper harmonic is tuned. All other stages are tuned in a similar manner using successively metering points 9, 11, and 12. The output resonator is tuned for maximum output into a load or antenna. Output loop L_{13} should be adjusted for maximum output.

The following table gives representative readings obtained with a 20,000 ohms-per-volt analyzer connected to various stages.

Analyzer Lead Connections		Meter Reading
+	−	(Volts)
Ground	1	0.6
Ground	5	3.2
Ground	7	33
Ground	9	33
Ground	11	15
12	Ground	8
4	3	65
3	2	30
4	2	103
4	6	5.2
4	8	8.2
4	10	7.4
4	L_{13}	23.5 ma
4	L_{14}	18 ma

The last two readings should be taken by opening up the plate supply leads and inserting the meter in series.

An output of approximately ¼ watt was measured using a Bird Wattmeter, Model 63-A. The output loop was made of No. 14 tinned copper wire with dimensions ¾ x ¼ inch. Using improved coupling means, it is expected to increase the output to ½ watt.

Acknowledgements

The author gratefully acknowledges the cooperation of the Hunt Corporation, Carlisle, Pennsylvania, who supplied the quartz crystals. In addition, he is indebted to the fine craftsmanship of Herbert Hardy, who constructed the final model and the test resonators used in the development.

References

(1) M. Marks, Cascade Phase Shift Modulator, ELECTRONICS, p 105, December 1946.

(2) W. C. Hollis, Design of Transmission Line Tank Circuits, ELECTRONICS, p 130, May 1947.

(3) A. P. Green and C. T. McComb, Resonance in Mica Condensers, ELECTRONICS, p 19, March 1944.

Explosion-pressure recorder setup for use with remotely located capacitance-type pressure pickup. Operator adjusts bridge control unit with left hand and single-sweep generator with right hand while viewing pattern on oscilloscope screen through peephole alongside camera on hood. Unit at right is sweep tripper control unit

Measuring Pressures of

INVESTIGATIONS and tests to eliminate or reduce damage from explosions have been devoted to methods of preventing explosion damage in rooms or buildings, both from dust and from flammable liquid vapors. The method usually involved determining, in a specially constructed building, the ratio of free venting area to building volume required to prevent obvious excessive pressure or stress in the structure. The work has also included explosions in vessels and pipe lines with vapor-air mixtures and also mixtures of air with hydrogen and acetylene.

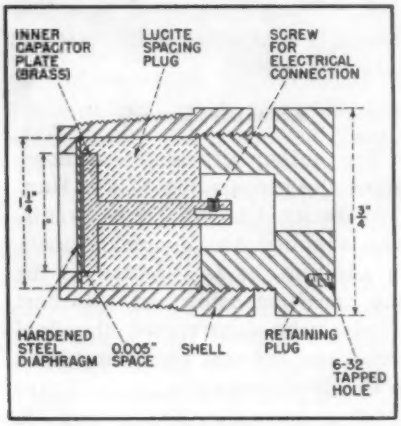


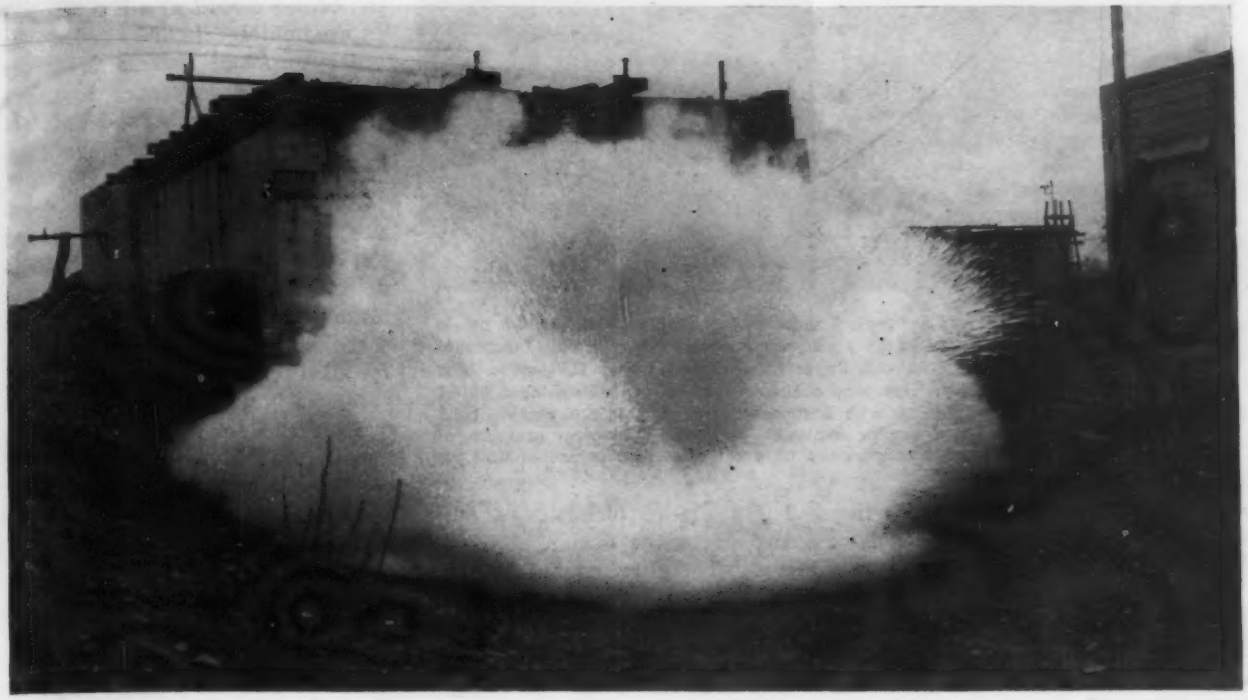
FIG. 1—Cross-section of capacitance-type pressure pickup. Sound waves act on steel diaphragm at left, causing capacitance between grounded diaphragm and insulated brass plate behind it to vary. Shell and retaining plug are turned from 1¾-inch hexagonal steel stock

Until recently, no wholly satisfactory instrument was available for obtaining pressure-time diagrams under such a wide variety of test conditions. Without an accurate pressure record there was no assurance that presumably identical explosion tests were being duplicated with respect to pressure, and the results of tests could not be applied with any degree of confidence to other conditions.

The pressure recorder described here meets all requirements for explosion research. It is adaptable to a wide range of maximum pressure, and it can be used for static conditions as well as for varying rates of pressure change, including those encountered in industrial explosions and water hammer. Because of the characteristics of the design, it is relatively independent of humidity, temperature, and extraneous pressure. A most important feature is that the design facilitates calibration in a very short time either before or after an explosion or other pressure test.

General Test Requirements

Occasionally tests are run which represent considerable time and expense for the setup, and it may be desired to obtain an accurate pressure record on an explosion which may not again be reproduced quickly, so that checking of results by many tests is not practical. Consequently, every individual test record should be completely reliable. Sometimes it is desired to measure pressures from an explosion the exact time of which is not predictable. For such cases the recording



Explosion of magnesium powder in a heavy concrete test tunnel at the Factory Mutual Laboratories is typical of accidental explosions but is set off under controlled conditions so that pressures can be measured and recorded to determine safety of various industrial conditions. Other tests include explosions of cleaning fluids in enclosed spaces and explosions of black powder in pipes

Industrial Explosions

Capacitance-type pickup feeds cro through 10,000-cps bridge to give pressure-time diagrams covering from 2 psi for dust explosions to 3,000 psi for gas-air mixtures in pipes, with calibration on static pressures. Automatic tripper circuit responds to explosions

By NORMAN J. THOMPSON and EDWARD W. COUSINS

Director *Research Engineer*

Factory Mutual Laboratories
Boston, Massachusetts

apparatus must be actuated automatically by the explosion pressure wave.

Some explosions, such as dust explosions in building structures, may give rise to maximum pressures of only two or three psi and the time required to reach peak pressure may be one-half second or even more. With other explosions, such as gas-air mixtures in pipe lines or closed vessels, maximum pressures may be of the order of 100 psi, or in some cases 2,000 to 3,000 psi, with pressure rise rates at very high values. Pressures due to water hammer in supply lines to sprinklers or in other hydraulic systems also develop very rapidly and may reach high peak values.

In explosion tests involving dusts or vapors in large areas, the decay of pressure may occur at such a slow rate that the pressure condition is almost static. Since the device must be used on static or near-static conditions, it is desirable to be able to calibrate the device statically in a very short period of time, either before or after any test.

In some tests it may be desired to locate the gage inside a building or

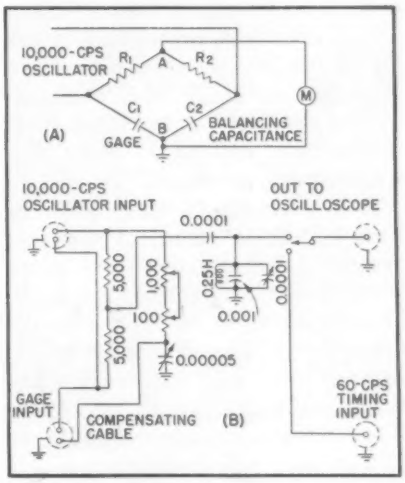


FIG. 2—Basic bridge circuit (A) used with gage, and final version (B) using tuned filter and compensating cable for limiting response to narrow band of frequencies around 10,000 cps

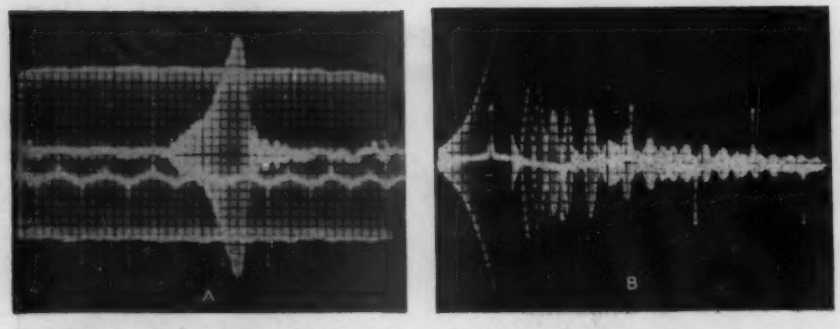


FIG. 3—Pressure-time diagram for typical industrial explosion producing 6.7 psi in 25 milliseconds (A), with peaked 60-cps timing wave and static calibration (horizontal traces) at 5 psi, as photographed with Super XX film at f/4.5 on 5LPI green tube using maximum beam intensity. Improved contrast (B) is obtained by using a 5LP11 blue tube at reduced beam intensity with Eastman Linograph 5244 film and an f/3.5 camera; this diagram is for a similar explosion producing maximum pressure of 7.6 psi, taken by means of automatic sweep tripper that started record at 0.57 psi

vessel as a space gage, whereas in other tests the gage must be external to piping or vessels.

In order to carry on varied experimental work, both inside and outdoors, it is essential that a pressure gage have certain characteristics. It should be accurate at least within 5 percent, and preferably within 2 percent or less. It should be able to operate satisfactorily at ambient temperatures from well above 100 F down to minus 50 F. Neither humidity nor transient temperature conditions should produce any serious error in results. The pressure pickup should be designed in such a manner that a wide variety of pressure ranges can be quickly and easily obtained by replacement of a simple element.

In the gage developed, a resistance-capacitance bridge circuit is used in which the pressure pickup acts as a variable capacitance in one leg of the bridge. Apparatus used includes an RCA 154 beat-frequency oscillator, a Du Mont 208B oscilloscope, and a Du Mont 215 single-sweep generator.

It is desirable in many cases to have a definite record of negative pressures, because there are times when these may not be so small nor of such duration as to be entirely disregarded. Experimental work on the new gage was conducted without such differentiation (that is, in a condition of complete balance at zero pressure) because this revealed the most about the gage characteristics. However, negative pressures can be shown easily by adjusting the bridge circuit to an unbalanced condition at zero pressure.

The pressure pickup was built according to the design shown in Fig. 1. The diaphragm thickness may be selected to accommodate a wide range of maximum pressures. For use as a space gage the hole in the retaining plug would be threaded to accommodate half-inch pipe or conduit to support the gage and shield the connecting cable from temperature and pressure changes. The conduit, plug, and shell would be grounded.

Circuit Characteristics

In order to utilize the special pickup, its capacitance and the capacitance of the connecting cable are balanced out so that only a change in capacitance will be indicated. A conventional RC bridge circuit is shown in Fig. 2A in which C_1 is the gage, C_2 the balancing capacitance, R_1 and R_2 the resistance elements of the bridge, and M a current or voltage detector.

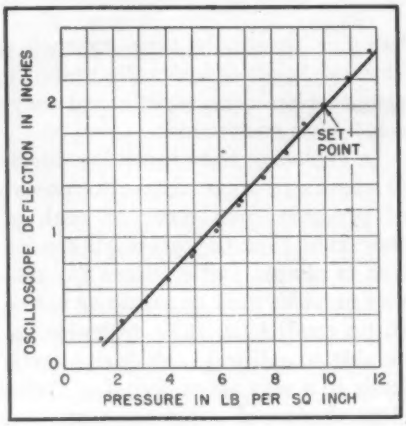


FIG. 4—Static calibration curve of pickup when using 0.02-inch thick steel diaphragm

It was found desirable to energize the bridge circuit at a frequency of approximately 10,000 cycles. In order to avoid serious frequency drift, it was necessary to use a voltage regulator between the 60-cycle power supply and the beat-frequency oscillator.

For maximum facility in operation, it would be desirable to ground the shell of the gage, the voltage detector, and also one side or a center tap in the power supply, but there is of course no common point for all three. Accordingly, for high-speed work, where it is necessary to use a cathode-ray oscilloscope as a detector, it is essential that the oscilloscope be grounded in its connection at point B, which requires that the power supply be isolated from ground.

It was found necessary to shield thoroughly all parts of the bridge circuit and its controls in order to eliminate 60-cycle pickup, some of which came through from the oscillator and could not be entirely balanced out. Grounding the center tap of the oscillator output transformer would eliminate most of the 60-cycle current transmitted from the oscillator, but this would bypass the bridge circuit with a signal direct to the grounded oscilloscope.

Attempts to eliminate 60-cycle current by inserting a small capacitance in each lead from the oscillator resulted in no advantage because even though the 60-cycle current was eliminated, harmonics of the oscillator frequency appeared, undoubtedly due to the inductance of the beat-frequency oscillator output transformer. Similar difficulties, either by generation of or sensitivity to high-frequency voltages, resulted from an attempt to use a simple inductance choke between the bridge output and ground.

The final solution, which gave satisfactory results, involved the use of a tuned filter connected across the oscilloscope input to reject all but a relatively narrow band of frequencies around 10,000 cycles. This was accomplished by the use of a 250-millihenry choke in parallel with a 0.001-μf capacitor with a variable vernier, as shown in Fig. 2B. With this circuit it was possible to balance the bridge to a point where the residual unbalance was about 0.001 volt, equal to 0.1 inch

deflection on the oscilloscope with its amplifier adjusted to maximum sensitivity. Since the bridge has a ratio of unity, and the applied 10,000-cycle current to the bridge is approximately 30 volts peak, this represents a balance to within 1 part in 15,000.

In actual use, it was noted that there was occasionally considerable zero drift. This was caused by a change in temperature, and was almost wholly due to changes in temperature of the single-conductor microphone cable (20 feet long) used to connect the gage to the bridge circuit. Both resistance and capacitance of the cable were affected. To correct for these factors a two-conductor cable was substituted, with one inner conductor and the grounded outer shield connecting the gage and bridge, and the other inner conductor connected in parallel with the balancing capacitance of the bridge. In spite of this balancing arrangement, the cable was found to be somewhat pressure-sensitive. If the pickup is used as a space gage, it would be desirable to enclose the cable within the space by pipe or conduit.

Application to Explosion Tests

In a series of preliminary tests, the gage was used to measure the pressure required to break glass panes (14 x 19 inch) in one side of a 3 cu ft enclosure and subjected to explosions of flammable liquid vapors with air. A typical result is shown on Fig. 3A with accompanying 60-cycle timing wave.

Other tests included breaking a 0.003-inch thick paper diaphragm by explosions of black powder in a short length of 6-inch diameter pipe. A typical result is shown on Fig. 3B. These pictures were made with the 0.020 inch thick diaphragm in the gage; the static calibration for this diaphragm is given in Fig. 4. With a maximum useful range of approximately ten pounds per square inch, there is a range of about 10 psi where the departure from linearity is less than 0.2 psi.

When using this gage near maximum oscilloscope deflection, the speed of travel of the beam at 10,000 cycles is too fast with the usual green cathode-ray tube to give photographs having maximum sharpness. One solution for this would be the use of a rectifier between the bridge and the oscilloscope input. However, this would require an amplifier capable of a wide range of frequency amplification down to and including direct current for static calibration. The difficulty was overcome by substituting a cathode-ray tube of much higher actinic intensity, the blue Du Mont 5LP11.

For explosions the exact time of which can not be predicted in advance, an automatic tripper circuit was developed, utilizing a 6C5 amplifier and a 2051 relay tube as in Fig. 5. The input is taken from the oscilloscope deflection plate, and the output is connected to the single-sweep generator. This equipment operates on a signal (with some adjustment) equal to about 3 percent of the maximum useful deflection of 2 inches but under such adjustment it is especially sensitive to exterior electrical disturbances such as turning on and off an incandescent lamp. In actual practice the adjustment was made so as to trip at 0.1 inch deflection, or about 5 percent of the maximum. For explosion work the loss of the first fraction of the record is of no importance. Possibly for other applications it might be worth while to develop a satisfactory delay, so as to be able to photograph the entire pressure-time diagram.

Stability and Pressure Range

The shape of the calibration curve is affected only slightly by the initial spacing between the gage plates; within practical limits the calibration of the pressure pickup is essentially independent of the spacing. The pickup was disassembled many times with only a minimum of care to recover the same initial spacing (about 0.001 inch with normal takeup). In each case when a known pressure was applied to the pickup and the gain control on the oscilloscope adjusted to give the same deflection as the original calibration, other pressure points also fell on the original calibration curve. This is important since it eliminates any necessity for careful temperature compensation.

The stiffness and consequently the linear limit of indication of similar diaphragms of different thicknesses will vary with the cube of the thickness. Practically, in order to obtain an essentially linear calibration, the deflection of the diaphragm at its center should not exceed 50 percent of the initial spacing. This relation of thickness to useful limit was shown by test to be true in calibration of diaphragms of 0.010, 0.020, and 0.030-inch thickness. Accordingly, the maximum useful pressures of hardened steel diaphragms of various thicknesses would be 1.5 psi at 0.010 inch, 12 psi at 0.020 inch, 40 psi at 0.030 inch, 100 psi at 0.040 inch, and 200 psi at 0.050 inch. The natural vibration frequencies of these diaphragms are respectively 3,960, 7,920, 11,900, 15,800 and 19,800 cycles per second.

Since the modulus of elasticity in compression of Lucite is of the order of 500,000 psi, this material cannot be used safely in the design shown at pressures beyond about 3,000 psi. Bakelite or other insulators having higher compression modulus would have to be substituted, but these have a higher dielectric constant which should be avoided. It would be best for operation in the range up to 10,000 psi to use a design in which the diaphraghm and shell are combined integrally by machining from a single piece of steel, thus avoiding strain on the insulating space plug.

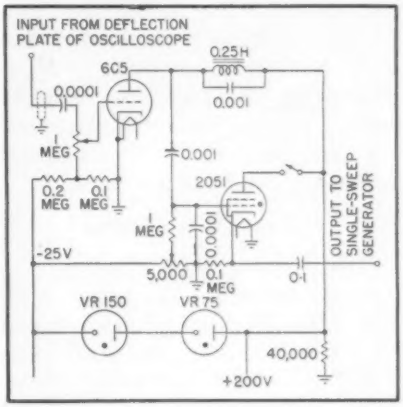


FIG. 5—Automatic tripper circuit for starting single-sweep generator when voltage on deflection plate of cathode-ray oscilloscope reaches about 5 percent of maximum

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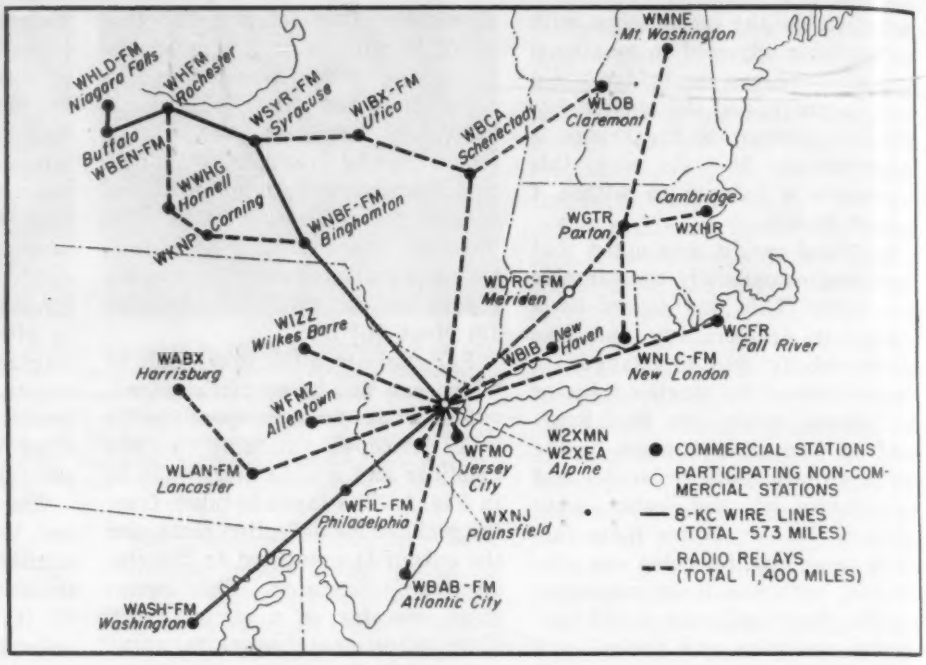


Map of the Continental Network as of Sept. 15; WSBA-FM, York, Pa. has since been added. Wire and f-m relay paths are shown by solid and dashed lines respectively

F-M Chain Broadcasting

Economic salvation for the small f-m broadcaster may lie in the methods of relaying high-fidelity programs from one station to another now used by the Continental Network and others. Techniques employed successfully since 1939 include one that does not require conversion to audio

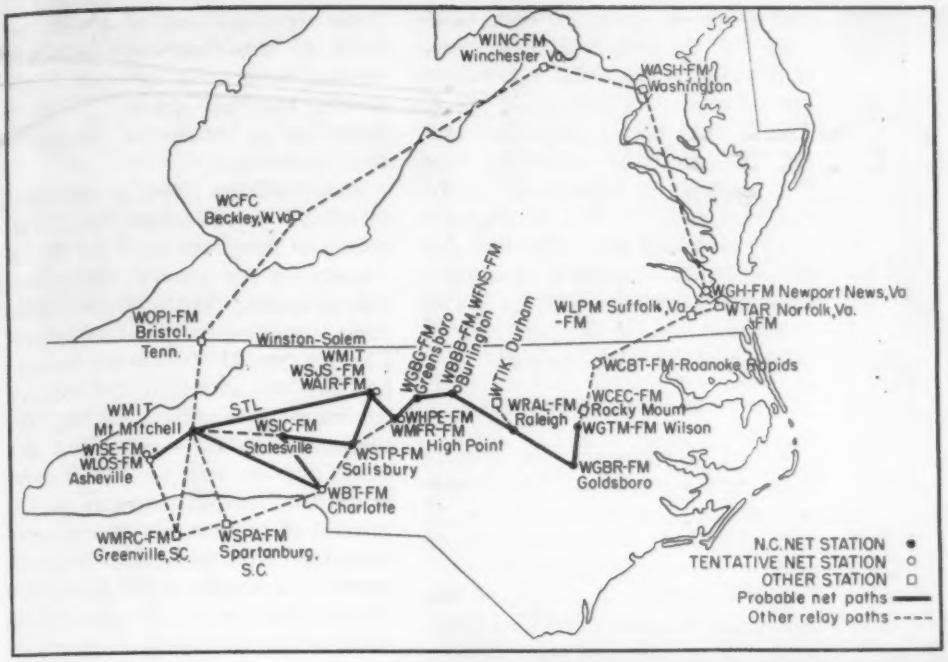
THERE are many aspects to the problem of f-m broadcast economics, all leading to the important consideration, can f-m pay its way? One important factor is how to utilize a good, and probably expensive, live-talent program on two or more stations, each of which is located in a mutually noncompetitive market area. This is a problem that can not be solved by the vice-president in charge of advertising sales alone, nor by the technical director alone. But both these men know, or should know, that they are treading on neither strange nor dangerous ground when considering the feasibility of chain f-m broadcasting.

A certain elementary book on calculus bears an inscription to the effect that what one fool can learn another can also. Although the f-m pioneers are certainly no more foolish than their new and enthusiastic colleagues, the methods by which they achieved success in a relatively uncharted area were less often dry victories of the slide rule than the adoption of Major Armstrong's philosophy,—"Make it work; then find out what makes it work". Newcomers in the f-m field may be heartened by a review of a successful past as well as by an active present. The facts are here.

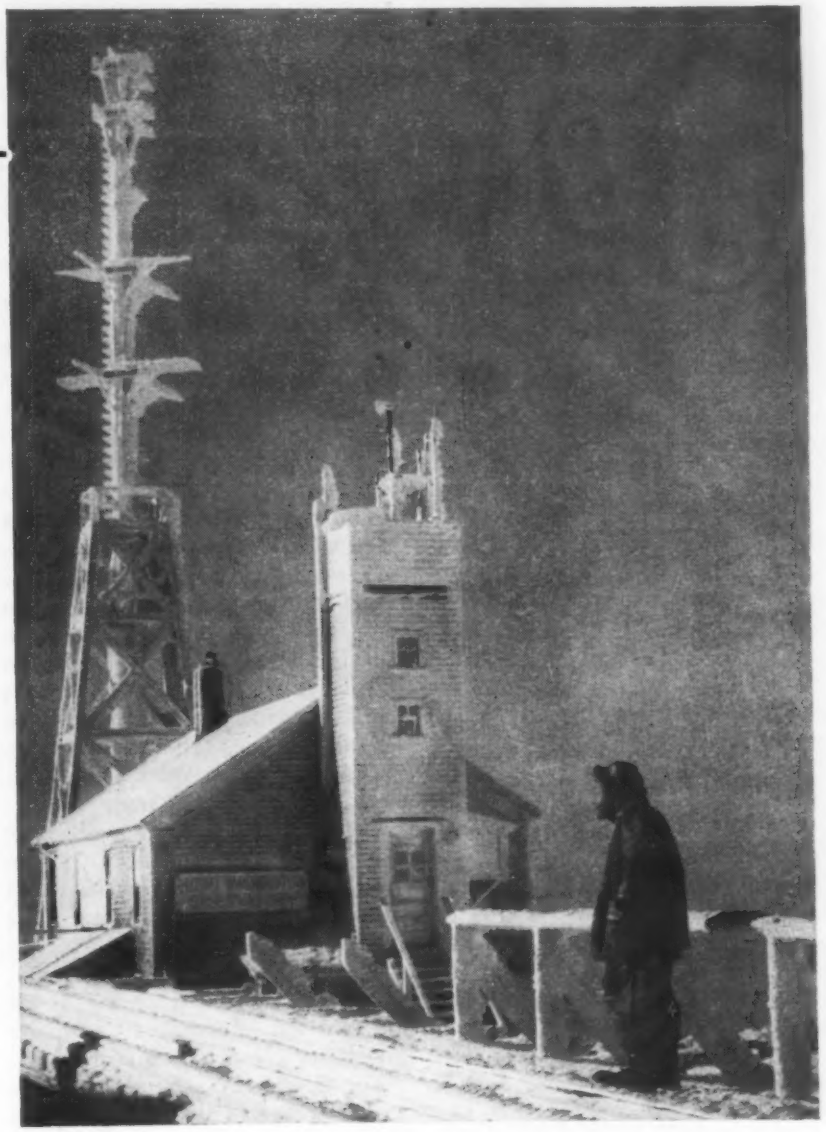
Original Relay System

The technique of relaying f-m programs from a high-frequency low-power station to a lower-frequency high-power station more suitable for broadcast coverage originated in the early experiments of E. H. Armstrong and C. R. Runyon, Jr., particularly between Yonkers, N. Y. and Alpine, N. J. Aware of the success of these relays, P. A. deMars, technical director of the Yankee Network, felt secure in planning a three-station network without wires. He had been further encouraged by frequent periods of good reception on Mount Washington, N. H. (37,600 feet below the optical horizon) of Alpine signals on 44.1 megacycles since 1938.

This original commercial relay system comprises a low-power transmitter operating on 156 megacycles (first assigned 133 mc) located on the roof of the Boston studios used to program the a-m and f-m stations of the Yankee Network. The signals from WEOD, Boston, are beamed towards the main 50-kilowatt transmitter WGTR in Paxton, Mass., serving Boston and southern New England, and are picked up there, about 45



North Carolina demonstration relay net planned for National Radio Week, Oct. 27-Nov. 1. Other possible relay paths are also indicated



Present northeastern terminus of the Yankee and Continental f-m Networks, on Mt. Washington, N. H. The upper bays of the turnstile antenna are used for high-band transmissions

miles away, on a directional receiving array. The program is then broadcast on 44.3 and 99.1 mc and picked up on Mt. Washington, N. H., about 140 miles away, where it is rebroadcast from WMNE, serving northern New England on 45.1 and 100.5 mc. Broadcasts from Paxton started in May, 1939 and from Mount Washington during the winter of 1939–40. Although there have been failures at various points in the circuits the total time off the air has been such an extremely small fraction of the total that it has never been considered necessary even to install local turntables and transcriptions so as to provide local sustaining programs during repairs.

In general, two modulator equipments are provided at each station. The class-C amplifiers following are not overworked and give relatively

Beam antenna for 156 mc atop Yankee Network studios in Boston is used to program Paxton transmitter about 45 miles to west

little trouble. In a few instances, the 50-kw pushpull amplifier at Paxton was operated from several hours up to two days with only one tube filament lighted. Slight retuning of the final was necessary, but the majority of listeners were never aware of the impairment to the signal strength.

Cost Considerations

Time has indeed shown the feasibility of the Yankee Network system, but the original daring conception of the network was predicated on two points. Although it might have been possible to program the Paxton transmitter by a wire line, such facilities were not then available. The best offer that the telephone company could make was a line reasonably flat from 30 to 15,000 cycles at an initial cost, to be borne by the broadcaster, of more than $75,000. The usual toll charges for use of the facility would follow. There could be no guarantee that the line would be noise-free. On that account, the radio program circuit was adopted as a major tenet of the plan, and Radio Engineering Laboratories furnished a unique 133-mc transmitter built to Major Armstrong's specifications at a fraction of the wire line cost.

Inaccessible Location

Mount Washington is remote from good wire lines. The broadcasting facilities designed to use to best advantage the summit of the peak were approachable, at best, through 7 miles of woods, to the foot of the mountain, and then three miles upward along a cog railroad. Although winter telephone communication has been maintained off and on since 1932 along this route, the cost of installing high-fidelity lines from the nearest suitable toll center and maintaining them in the high winds and other generally inclement weather would be extremely costly. Practically, the only way to program a Mount Washington transmitter is by radio link.

The techniques and equipment required for the relay system are simple, but the actual installations made were designed for less than optimum conditions. At the Boston studios (WEOD), a 3-element array of dipoles, reflectors and directors mounted one above the other on a steel mast on the roof of the building was used. At Paxton a pair of multiwave vee antennas, one above the other and each backed by a closely spaced parasitic reflector, furnished more than adequate gain for the program receiver used. In actual practice, the final amplifier in Boston was discarded at the time of a change in frequency assignment from 133 to 156 mc. Besides tolerating a power reduction at the relay transmitter, it was found that under conditions of abnormal icing at Paxton a simple dipole with reflector and director, mounted behind a glass-block wall near the 50-kw transmitter, furnished adequate signal for the program circuit.

On Mount Washington where small structures must be protected from accumulations of ice or the force of superhurricane winds, a wooden tower was included in the special building design to house receiving or emergency transmitting antennas.

The receivers used in the relay technique were originally simply good f-m receivers built for Major Armstrong for general demonstration purposes. When Mount Washington went on the air, the General Electric type JFM-90 home receiver had become available and so this equipment was modified slightly for somewhat greater r-f gain and selectivity as well as for a more convenient output impedance. In general all these receivers were also provided with two audio outputs, one with a standard RMA restorer (de-emphasis circuit) for audio monitoring and the other maintaining the pre-emphasis introduced in the original transmitter. In this way, it is not necessary to restore and pre-emphasize the signal again at each succeeding station in the chain. At a later date, simple heterodyne converters were added to the JFM-90 receivers and they serve for reception on 156 megacycles as well.

Intercompany Relays

On Dec. 4, 1939, a program originating at W2XCR in Yonkers was picked up and relayed through W2XMN Alpine, then rebroadcast from W1XPW, operated by Franklin M. Doolittle at Meriden, Conn., since May 13, 1939. The success of this venture created considerable furore and K. B. Warner of the American Radio Relay League stated: "In 10 years there won't be any orthodox brand of broadcasting remaining except for the lowest grade of local service". Early in the morning of Dec. 29 a similar test program was tried again, this time including the Paxton transmitter. No difficulty was experienced when the Meriden program was picked up at a farmhouse somewhat lower in elevation than the station and sent through about a thousand yards of wire line to the transmitter modulator. The remote receiver and antenna were soon replaced by a local antenna and a receiver in the transmitter building. On Jan. 4 and again on Jan. 5, 1940, an hour's

program starting at 6 pm was originated in Yonkers and sent over the net for the benefit of regular listeners. Mount Washington received the program and relayed it by a-m to the communications center in Boston, where it was put on a telephone line and returned to Yonkers.

On Feb. 21, the Paxton program was successfully rebroadcast during a 15-minute test by the a-m stations WNAC Boston and WEAN Providence. With this success, a new chain was composed for a half-hour broadcast on the evening of Feb. 29, using W2XAG Yonkers (key station), W2XMN Alpine, W1XPW Meriden, W1XOJ Paxton and W1XER Mount Washington,—all f-m stations. In addition, the Alpine broadcast was picked up by a-m station WICC Bridgeport. Stations WEAN Providence, and WAAB Boston picked up the Paxton broadcast. Listeners in Boston to the Mount Washington f-m broadcast felt that it was fully as good as that from Paxton.

Further relay experiments conducted during 1940 were complicated by the continual violent evolution of the stations. At Paxton alone from May 1939 until May 1941 transmitter power was raised from 2 to 50 kilowatts and three different types of turnstile antennas were tried. One imposing 400-foot tower toppled over in an ice- and wind-storm early on the morning of Jan. 15, 1940. Every change in transmitting power or antenna required at least a slight change in the receiving setup.

Yet despite these difficulties it was possible to relay a live half-hour dinner music program from Meriden through the Yankee f-m network six days a week from January until December, 1941, as well as a number of other irregularly scheduled chain programs. On July 17, 1941, a special program was broadcast from Paxton for the dedication of W47A Albany, and thereafter for some time the bulk of the Albany station's program material consisted of rebroadcasts from the Yankee Network. On Nov. 30 the same year, the W71NY dedicatory program was heard over the network from New York after which live programs from Boston and Hartford were relayed in the reverse direction through the Meriden station.

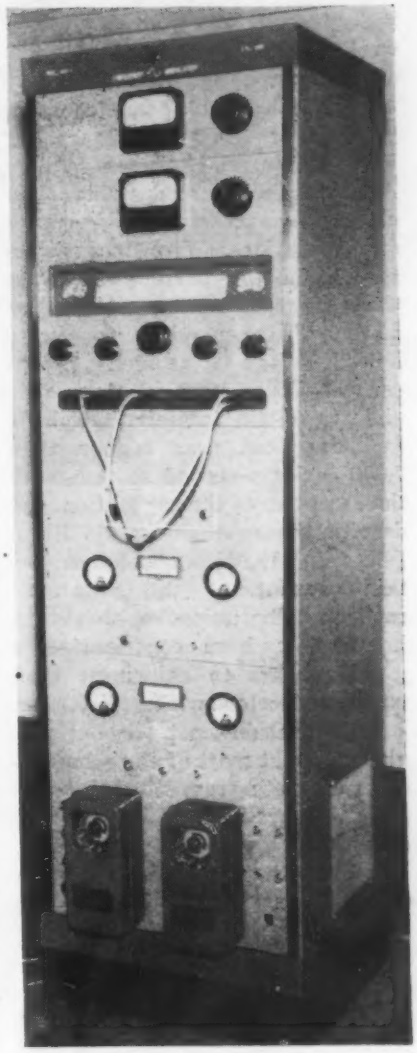
For three months, the Paxton programs were picked up at Trumbull, Conn., relayed on about 150 and later 200 megacycles, picked up at Alpine with a corner-reflector antenna on the middle arm of the famous tower, and fed via a coaxial line to the receiver that programmed the Alpine transmitter, providing a two-way circuit between Alpine and Paxton.

Some different relay techniques were also employed experimentally. Instead of receiving a signal, converting it to audio and using it to modulate another transmitter, the incoming carrier signal was caused to beat with a local oscillator so the difference frequency that was further amplified occurred at the assigned carrier frequency of the relay station. This system was used for some time with great success at Meriden in relaying to the north.

Beginning March 3, 1942, f-m chain broadcasting came of age when General Electric paid out cash money to sponsor the Frazier Hunt news program Tuesday, Thursday and Saturday evenings until May 29, 1943. The American Network chain included W53PH (now WFIL-FM) Philadelphia which picked up Alpine direct, W71NY (now WBAM) New York, W2XMN Alpine, W65H (now WDRC-FM) Meriden, W43B (Now WGTR) Paxton, W47A (now WBCA Schenectady) Albany and W39B (now WMNE) Mount Washington. The broadcasts went off with little technical difficulty, but unfortunately the program was transcribed—a fact only too apparent with the high-fidelity equipment used!

Postwar F-M

For a number of real and sufficient reasons, f-m broadcasting was unable to capitalize fully upon its rapid early gains and plateau of accomplishment after the cessation of hostilities in 1945. Because of the fear on the part of FCC that occasional long-range anomalous propagation would interfere with service areas far removed, new frequency assignments were made transferring the f-m broadcast band from 40–50 megacycles to 88–108 megacycles. Transmitters with any appreciable power were not immediately available for the new band.



Radio-relay receiving panel used at FMA convention demonstration. Two vu meters for monitoring, high and low-band tunable receiver, jackfield, amplifier, and two fixed-tune receivers can be switched at will or automatically by time clocks below

With understandable if not commendable hesitancy, many manufacturers of receivers put off the evil day when a choice would have to be made whether to manufacture high-band or high-and-low-band f-m receivers, or no f-m receivers at all. F-m program material generally deteriorated or broadcasting time was cut because of an edict from the head of the American Federation of Musicians banning duplication of a-m programs on f-m stations unless suitable quid pro quo was forthcoming from the broadcasters.

Once again, under the aegis of the pioneers the Gordian knot has been

Temperature Control for Octane Tests

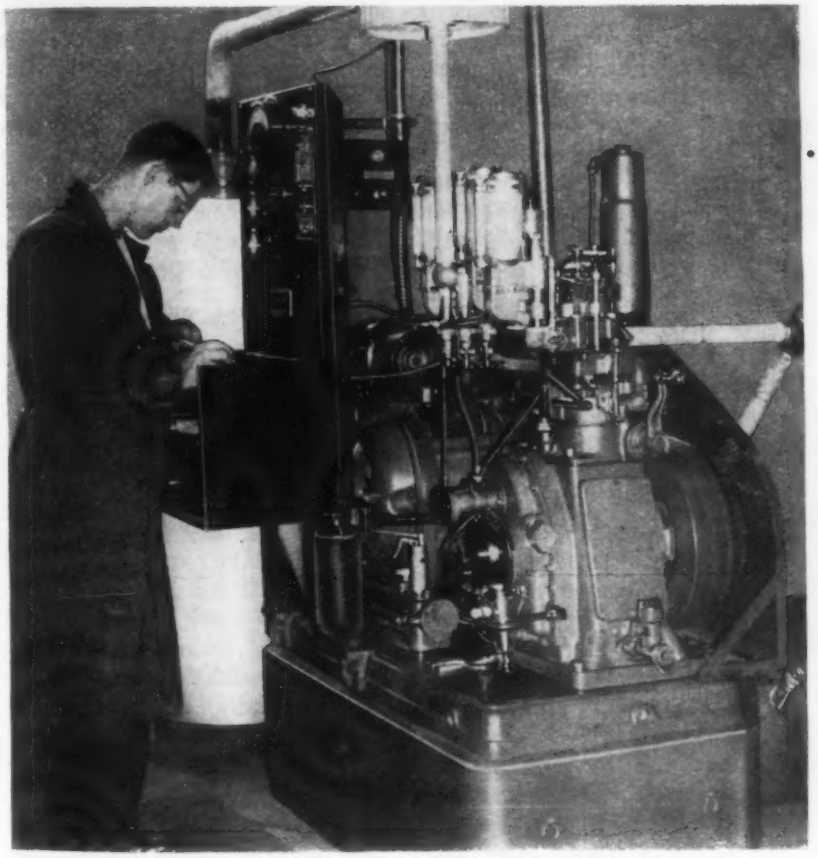
Transformless vacuum-tube relay circuit controls temperature of gas-air mixture fed into knock-testing engine by switching electric heater from low heat to high heat as often as 250 times per minute. In industrial service, the 117N7GT tubes used are highly reliable

By PIERRE J. MALRAISON

Mount Vernon, N. Y.

CONTROL of the temperature of the gasoline-air mixture fed into a knock-testing engine presented a series of interesting technical problems. According to ASTM specifications, the mixture temperature must be maintained at 300F ±2F as indicated by mercury thermometer. The equipment described here has been approved as optional by the ASTM.

The fuel intake system of the engine is diagrammed in Fig. 1. Air is supplied to the carburetor where it is mixed with atomized gasoline. The gasoline and air mixture passes through a heater housing containing a two-blade 1-kw immersion-type heater. It then passes around the bulb of the indicating thermometer and into the engine.



Knock-testing engine in Ethyl Corporation plant, using Malraison Mixture Thermostat for maintaining temperature of gas-air input mixture within 2 degrees of 300 F as indicated by mercury thermometer. Vacuum-tube relay housing is mounted behind control panel at eye level

The operating temperature of the mixture is well above its flash point and only slightly below the fire point, so that the most minute spark in this portion of the system will cause a partial or total combustion of the mixture before intake, destroying the validity of the test. The lag of the heating system is very large compared to that of a system specifically designed for automatic control, but could not be changed without exhaustive test work to prove that the changes would not affect the existing data.

Bimetallic Thermostat

Tests showed that the most satisfactory sensing element for control was a bimetallic strip mounted in the intake stream of the engine as near the indicating thermometer as practicable, with contacts arranged to close with rising temperature. Since the volume of the heater housing is considerably less than the volume of the cylinder, the mixture travels through the housing at a high velocity during the intake stroke of each cycle.

An oscillation of the bimetal due to mechanical action of the mixture stream on the bimetal and to cooling of the strip as the tail of the

badly frayed. The Continental Network with WASH-FM Washington as key station, has been picking up since March 26, 1947 public-service concerts of Army and Army Air Force bands, relaying them by wire line and the rebroadcasting technique to an ever increasing network of f-m stations. Wire lines, necessary until the participating stations increase power or decrease distance between relays, constitute a bottleneck so far as fidelity is concerned. It has not yet been possible to obtain intercity telephone facilities that pass higher than 8,000 cycles a second so that with the exception of the key station, and despite the extensive radio links, (see map) the listeners lose a certain amount of the program's realism. The noise-free aspect is, however, a boon contributing a greater share to enjoyment than can be understood without listening.

It is probably not without significance that most of the relay circuits emanate from the older stations that are licensed to broadcast on both the low and the high bands. It is likely that consistent reception over distances possible with the low band may require greater power or more intermediates when the high-band frequencies are used.

At the moment of this writing Continental has grown to 28 stations, using 573 miles of wire line and over 1,400 miles of radio relays, and is still expanding rapidly. Starting Sept. 12, 1947, commercial operation of the network was begun with a half-hour program from WHFM Rochester sponsored by Stromberg-Carlson following a half-hour sustaining show. The schedule was varied on the first evening to include a pickup from the Frequency Modulation Association convention in New York where previously the delegates had heard Alpine broadcasts sent from Boston via three relays and one from Allentown, Pa. in two hops.

More than 90 applications have come in to Everett L. Dillard of WASH-FM, president of the Continental Network, requesting affiliation, one from the owner of a potential chain to cover California. There are inquiries from Florida and the Gulf states. The most immediate interest is in a plan that calls for a telephone line to Chicago with satellite relay stations branching from the wire line to the north and south.

Practical technical limitations to the length of a relay chain without wires is unknown, so that future plans for expansion will depend on further experience. The heterodyne frequency-changing method used successfully at the Meriden station is thought to be the most satisfactory solution, and the technique is being further developed experimentally.

The North Carolina State Hookup

The mountainous region in the Carolinas has proved, like New England, a fertile ground for f-m broadcasting. A-m signals are so rapidly attenuated that it is not economically feasible to give large segments of territory with small populations adequate or enjoyable service. F-m, on the other hand, is much less adversely affected by the terrain, particularly since high land is available for the siting of stations.

Plans are being formulated by the North Carolina FM Association for a statewide, one-time hookup of f-m stations that are on the air in time to participate in a broadcast to take place during National Radio Week, Oct. 26 through Nov. 2. A map included here shows the ten stations most likely to take part as heavy dots and the six remaining licensees as open circles. Relay paths expected to be used are indicated by solid lines. These circuits will probably be used in both directions as each station takes over as key station of the net, puts on its best program and then retires to a relay function as the next station originates rather than relays a program. The stations shown as squares are added to this map for convenience, but will not take part in the Radio Week hookup. The dotted lines show circuits that have been already tried experimentally or seem feasible for obvious reasons, indicating possible future potentialities for relaying.

Missouri-Kansas Net

Aside from the many inevitable studio-transmitter links connecting remote transmitters with their program source, there are other station networks now in operation or in the formulative stage. Ambitious plans for a Missouri-Kansas network have been set into motion by the establishment of a receiving station atop the Kansan Hotel in Topeka, Kansas for reception of KOZY, Kansas City, Mo. One half-hour show each Sunday is by this means picked up and rebroadcast by WIBW-FM. As soon as station facilities at KOZY, now undergoing alteration, shall have reached a stable state more extensive hookups, possibly on a commercial basis, will be tried.

Owners of Radio Diablo, operating a 50-kw high-band transmitter, are considering establishment of a relay network that will tie together Los Angeles and Mt. Diablo, Calif. The latter station will then program transmitters in outlying communities roughly representing a hub to the spokes formed by the relay circuits.

Although f-m relays can do much to aid the growth of a new broadcasting service and the inexpensive dissemination of good programs, the time may eventually come when the f-m broadcaster will find it necessary to re-evaluate his position. A few moments, or even an hour of lost time from a sustaining program at this stage of the game can be tolerated, although it is undesirable. When more and more commercial programs are handled, the broadcaster may find that the additional expense of wire lines is still less than the maintenance of standby equipment at each station in a long chain. While it is still too early to predict the exact shape of the combined wire and relay facilities to be used by f-m broadcasters, it seems safe to assume that nearly as many miles of wire, coaxial, or microwave circuits will be used in the future as for the present major a-m networks.

Acknowledgments

Thanks are due a large number of people for information made available. The author feels particularly indebted to E. H. Armstrong, E. L. Dillard, F. M. Doolittle, F. A. Gunther, P. Hedrick, B. Ludy, and I. B. Robinson as well as to other members of their organizations for friendly assistance. —A. A. McK.

Vacuum-tube relay unit. Phantom view of cover was obtained by taking two exposures on same negative, one with and one without cover

ered in many industrial plants. The rectifier and electrolytic capacitor provide sufficient filtering to eliminate synchronization with power line frequencies.

The circuit is arranged so that plate current flows with the grid circuit open. Adjustment of the various clearances, spring tensions, and the cathode circuit potentiometer are made so that when the Micro Switch is used as an interrupter in buzzer fashion and connected into the grid circuit, the relay will operate at a minimum rate of 20 times a second at 95 volts a-c input and 30 times a second at normal line voltage of 117 volts a-c. Acceptance tests require that it shall continue to function at 140 volts input. These speeds are adequate for the control of temperature on engines in the ASTM motor, research, and aviation knock-testing methods.

In order to provide continuous service from an installation it is customary to change Micro Switches after approximately 2,000 hours of service. On breakdown tests, switches have operated in excess of 7,000 hours. While these times of operation do not appear impressive, it is to be noted that the contacts can operate as often as once per intake stroke or 450 times per minute for the 900-rpm ASTM motor method. By actual count, contact closure occurred an average of 250 times per minute, which means that 2,000 hours is equivalent to 30,000,000 contact closures.

Since the installation of the switch and adjustment of the relay to these operating conditions are fairly critical, the relay has been assembled on a plug-in mount so that the changeover can be facilitated and factory service of the units easily provided. Parts requiring adjustment for individual installations, such as the 0.5-megohm resistor and a 7-ohm adjustable series resistor, are installed in a junction box having a receptacle for the plug-in amplifier unit. The series resistor is adjusted to give a 2-ampere reduction in electric heater current on a 110-volt line. The line voltage is adjusted so that the average of the high and low heater currents is approximately equal to 7.5 amperes on 110-volt lines. This is accomplished by means of the standard manual temperature-control rheostat supplied with each engine for the electric heater.

Operation of Relay

When the engine is started, the Micro Switch is open and current flows through the series resistor to the electric heater. As soon as the 117N7 tube has warmed up to the point where plate current is drawn, the relay pulls in to close the Micro Switch, permitting high-heat current to flow directly to the heating element. As the temperature of the intake mixture rises, the mean position of the bimetallic strip moves nearer the adjustable contact. As the temperature approaches the desired point, the bimetallic strip makes instantaneous contact at the crest of its upward movement, grounding the grid of the tube and cutting plate current nearly to zero. The relay drops out and the Micro Switch opens, thereby removing the short from across the series resistor and reducing the current to low-heat value.

As soon as the momentary contact is broken, the plate current goes up and initial high-heat conditions are restored. As temperature continues to rise, the time of contact closure on the bimetal increases until an equilibrium is reached at which the correct average heat input is supplied.

Variations in line voltage, ambient temperature, and latent heat of fuel are compensated for automatically by changes in the time of contact closure. It is notable that the approach to equilibrium is asymptotic and that the equilibrium is mobile. Under these conditions the system provides a degree of anticipation of heat requirement which permits stability within the desired limits even with rapidly varying conditions. For instance, when changing from fuel to fuel by means of the carburetor selector valve, with benzene having a latent heat of about 75 calories per gram in one bowl and ethyl alcohol having a latent heat of about 200 calories per gram in another, sensible equilibrium was reached within one minute.

Except in one instance when the fuel could not be vaporized in the heater housing and both the bimetal and thermometer bulb became wet with fuel and therefore could not be depended upon, it has always been possible to maintain thermometer readings constant within ± 2 degrees F. Under average conditions, control to ± 0.5 degrees F is readily achieved and certain operators have reported even closer control.

The author wishes to acknowledge the cooperation given him by J. C. Pope and E. N. Garnsey of the Ethyl Corporation in designing and testing the initial equipment.

OTHER INDUSTRIAL APPLICATIONS

Similar relay units have been used to control the temperature of water baths to within 0.0001 degree C and air baths to within 0.001 degree C

With suitable hair hygrometers or humidity-sensitive resistors, the unit is readily adapted for control of humidity

Use of photoelectric input provides a rugged counter, alarm circuit, or safety circuit for industrial use

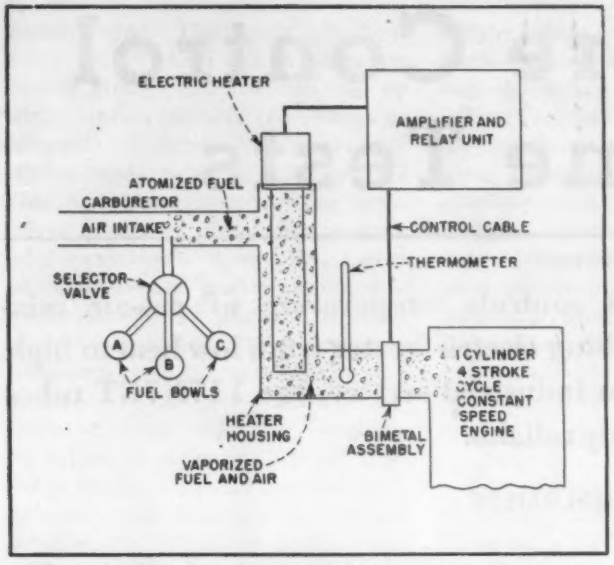


FIG. 1—Block diagram of knock-testing engine used for determination of octane ratings of various gasolines in refineries and petroleum-testing laboratories, showing location of bimetal assembly used with vacuum tube for temperature control

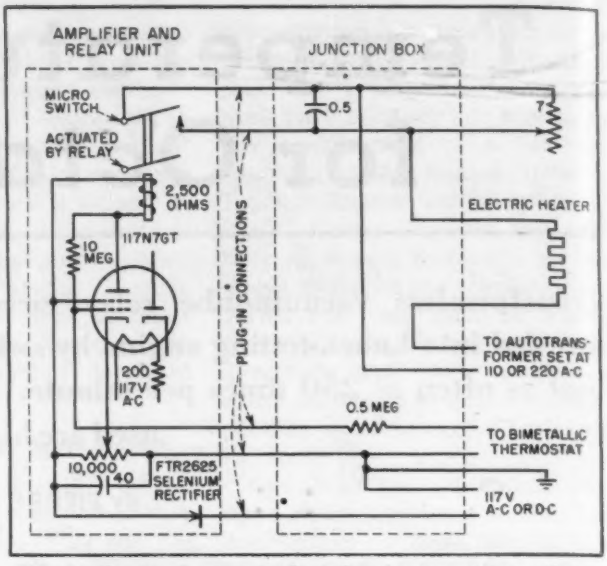


FIG. 2—Circuit of vacuum-tube relay having unique advantages for industrial control applications. Plug-in feature permits carrying standby unit in plant for quick replacement of entire amplifier unit in case of tube failure or other trouble

charge passed through was noted. Although no measurements of these rapid changes in temperature have been achieved, it is obvious from the characteristics of the system that they are present. The bimetal contacts are connected into the grid circuit as shown in Fig. 2.

Contact Problems

In initial tests a conventional vacuum-tube relay was used, with raw a-c fed to the plate and with a capacitor across the relay coil to eliminate chatter.

A spark (believed due to the discharge of the grid-cathode interelectrode capacitance) was observed at the contacts of the bimetallic strip. The current at this point is of the order of microamperes and gives no spark with the tube disconnected. A 0.5-megohm resistor in series with the grid of the tube successfully eliminated the spark.

The lag of the heating system was so great that it was impossible to achieve control to better than ±15 degrees F with complete on-off operation. A variable autotransformer was inserted to limit the high-heat current, and a series resistor shunted by the Micro Switch in the vacuum-tube relay was installed to limit the low-heat current. In order to provide temperature control to ±1 degree F it was found necessary to adjust the differential between high heat and low heat to such a small value that manual control was required to compensate for any but the smallest changes in temperature-influencing factors. The capacitance across the relay coil was then reduced so that the relay would respond to 10 contacts per second and a passable degree of automatic control was achieved. Under these conditions the switch life varied from 4 hours to 1,000 hours, depending on the installation.

Since a relay which gave a thousand hours service in one laboratory gave 4 hours service in another (where an isolation transformer was required between the line and the relay), it was guessed that some sort of synchronization occurred between the power line frequencies and the operation of the relay. This guess was confirmed by inspection of the switch contact points, which in every case had the characteristic appearance of having carried direct current. In other words, the contacts were always breaking on the same portion of the a-c cycle.

A rectifier and filter capacitor were inserted to provide d-c plate current for the tube, and the capacitor across the relay was removed from the circuit. Inspection of the switch contacts after 500 hours of operation showed a satin finish characteristic of a-c service. From the data obtained, an improved Micro Switch was developed for this relay and was used with a 0.5-μf capacitor shunting it to minimize oxidation of the contacts.

When the capacitor across the relay coil was eliminated, the time constant of the relay circuit was markedly reduced, permitting response to more than 60 contacts per second in the grid circuit. For a given differential between high heat and low heat, larger and more rapid variations in temperature influencing factors could now be compensated for automatically.

Relay Circuit

A universal a-c/d-c transformerless circuit is used in the relay because of the greatly varying power line voltages and frequencies encountered in industrial plants.

Tubes of the 117-volt series are used because they have low operating current requirements and thus dissipate less heat than other types. The power output type of tube is used because it has been found to give long, satisfactory operation when lightly loaded, as it is in this application.

The 10-megohm resistor connected between grid and plate assures that the grid will not block when the grid circuit is open. The 200-ohm resistor was inserted in the tube heater lead to overcome the effects of high line voltage encount-

Interconnecting Facilities for Television Broadcasting

Video facilities now available, or to be completed by 1950, include a 12,000-mile nationwide system using coaxial cable, local networks employing shielded-pair telephone cables, and microwave radio circuits. Provisions are made for direct connection of broadcasters' equipment to shielded-pair systems

INTERCONNECTING facilities for television broadcasting stations fall into two general classifications: short haul circuits, which include those connecting studio to transmitter, remote pick-up point to studio, and studio to point of interconnection with intercity networks; and long haul circuits which interconnect cities to form networks.

In both short haul and long haul circuits, the principal technical characteristics affecting the transmission of television signals are (1) frequency bandwidth, (2) echoes, and transmission and phase deviations, and (3) noise, modulation and crosstalk.

The bandwidth of a given television transmission circuit influences the definition obtainable with a particular rate and method of scanning. Reflections from objects in a radio path and from impedance irregularities in wire plant, which cause deviations in the transmission-frequency and phase-frequency characteristics of the circuit, produce ghosts in television pictures. Transmission and phase deviations resulting from causes other than reflections, such as imperfect equalization, give the same sort of picture ghosts. Reflections may be greater in one part of the band than in another. Thus, a high-frequency echo might produce a complete ghost of a thin vertical line, such as a flagpole, while the ghost of a wider object would show only at its edge. Very short delay echoes produce picture ghosts so slightly displaced that they merely blur the edges of sharp discontinuities in the picture. Long delay echoes, on the other hand, cause discrete images displaced from the principal image. These effects are minimized by introducing transmission and delay equalizers at amplifier points.

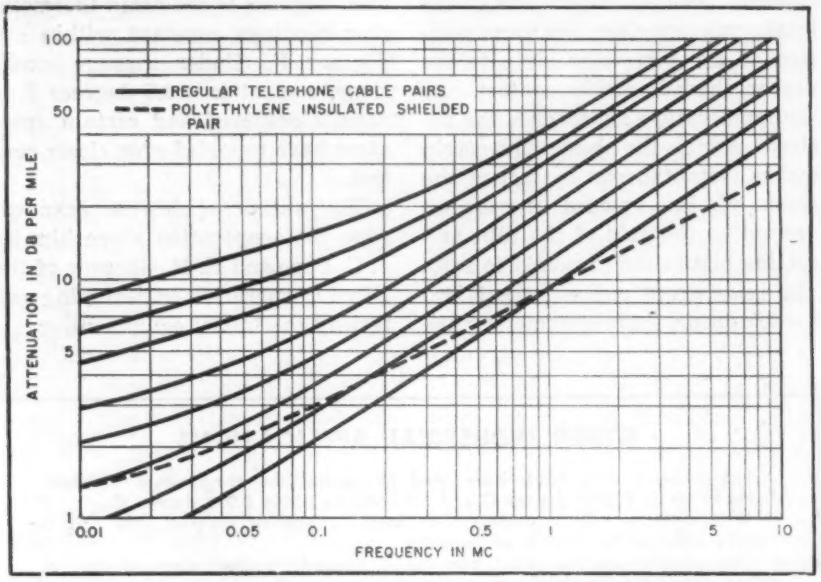


FIG. 1.—Transmission loss-frequency characteristics of regular telephone cable pairs as compared with the characteristic of a polyethylene-insulated shielded pair

Systematic noise resulting from harmonics of the power frequency produces objectionable patterns on the picture; resistance noise produces a general fuzziness and boiling effect. While raising the level of the signal can reduce the effects of the noise, modulation in the amplifiers tends to increase. This modulation usually produces spurious patterns appearing as sharp demarcations in brightness over the televised scene. Crosstalk from another television system produces a type of interference which shimmers, or crosstalk can result in the superposition of a weak copy of the picture from the interfering system.

Shielded-pair video cable is used for local television facilities; coaxial cable for intercity facilities. Use of polyethylene insulation in construction of both types minimizes transmission losses

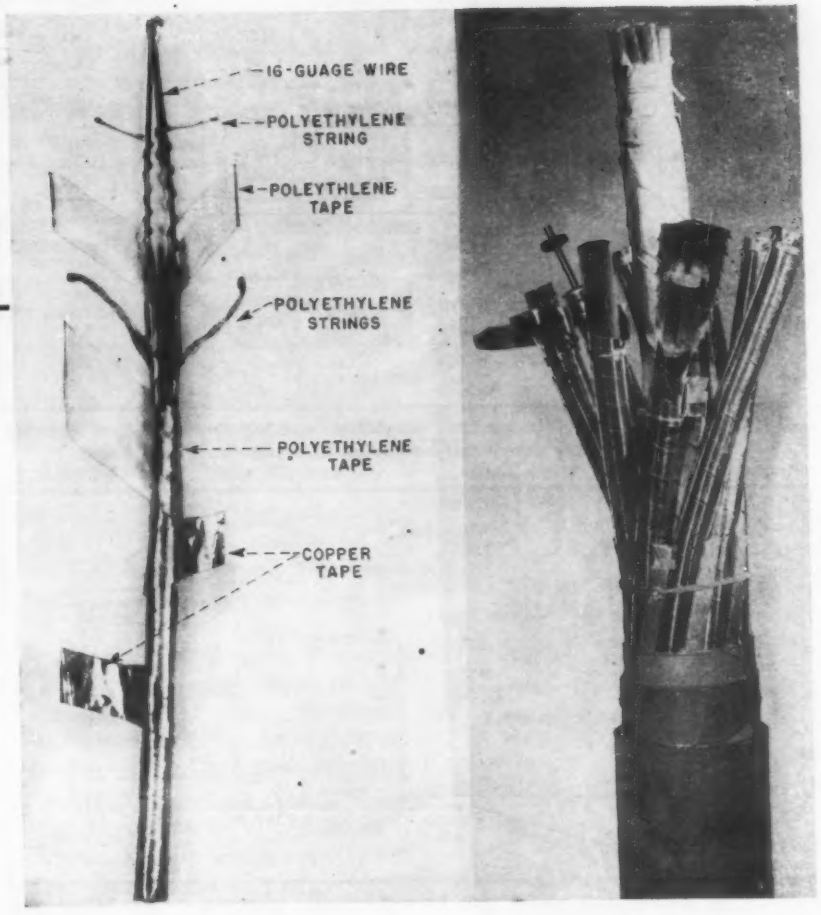
By W. E. BLOECKER
American Telephone and Telegraph Company
New York, N. Y.

Special attention in the design, operation and layout of facilities is required to provide adequate bandwidth for good picture definition, to eliminate ghosts and to minimize noise and crosstalk.

Short Haul Circuits

Short haul television facilities are usually equalized to accommodate a bandwidth of about 4 mc. Because of the relatively short lengths of local television circuits, carrier methods are not economical when wire circuits are used because of the cost of the terminal equipment. Transmission, therefore, is at video frequency, that is, in a band extending from the very low frequencies up to about 4 mc. The associated sound channels are furnished separately over regular program transmission circuits.

In large city areas, regular telephone cable pairs literally appear everywhere and consequently are attractive as a vehicle for television transmission. The transmission losses of such facilities at 4 mc, however, are high, ranging from about 94 db per mile, for the smallest gauge cable conductors in general use, to 36 db per mile for larger gauge conductors frequently found along main trunk routes. These attenuation figures compare with values of 7 db to 2½ db per mile at 8 kc for corresponding types of



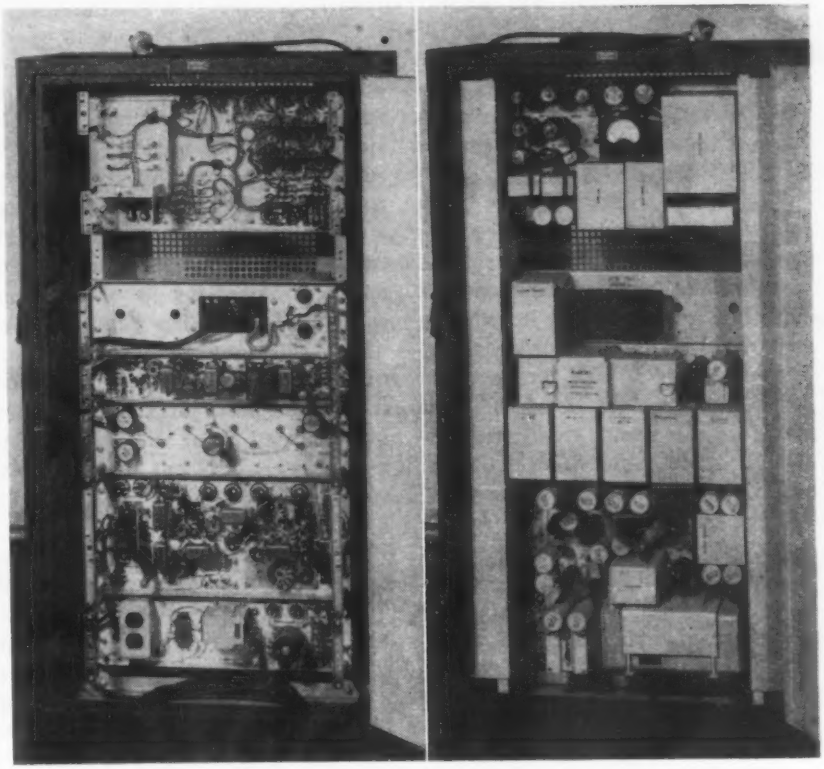


FIG. 2—Front and rear views of video amplifiers used in short haul circuits

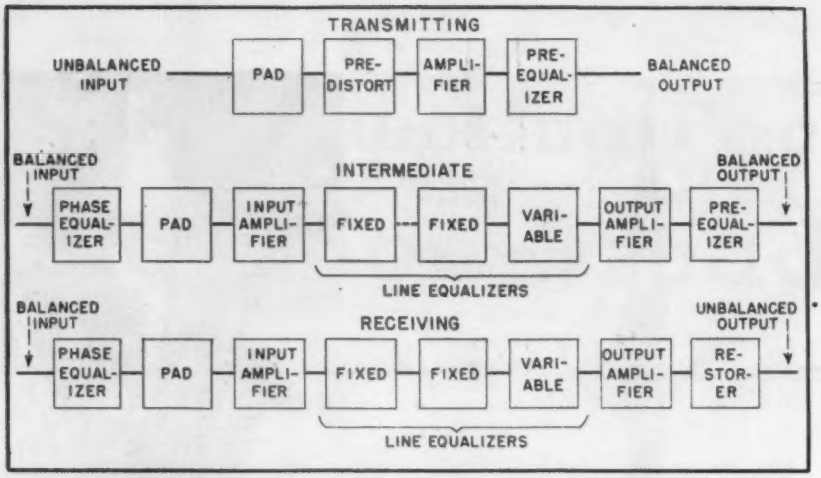


FIG. 3—Unbalanced-input transmitting amplifiers and unbalanced-output receiving amplifiers readily permit interconnection of broadcasters' equipment

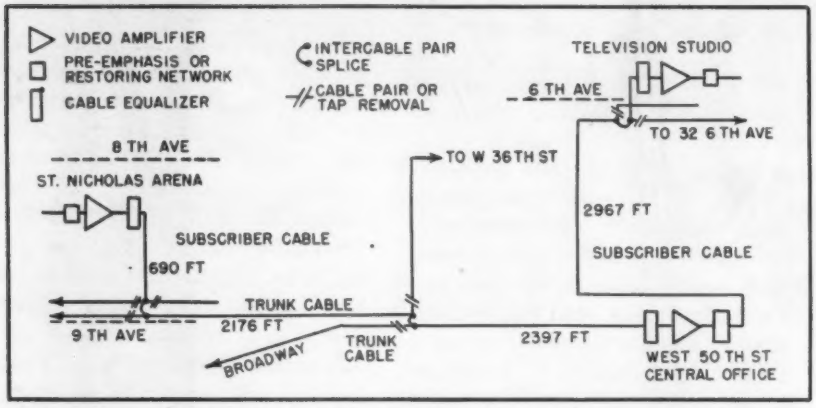


FIG. 4—A typical short haul circuit connects studio, telephone central office, and remote pick-up points

plant used for sound program transmission. Figure 1 shows representative attenuation characteristics of the usual types of exchange telephone cables.

The use of exchange cable pairs for television transmission requires special preparation such as the removal of all bridged taps and all cable stubs over 4 feet in length, the removal of any loading present, and in some cases special measures to reduce noise. Because of the high losses at the upper video frequencies, it is frequently desirable, in order to minimize the number of intermediate amplifiers required, to make special splices between cables to utilize available larger gauge cable conductors and obtain the most favorable routing.

The crosstalk coupling between cable pairs at the higher video frequencies is high, limiting the number of television channels which can be carried in a single cable sheath, even when they are operated at comparable levels in the same direction. Special coordination measures, usually involving separate cable sheaths, are required for oppositely directed television circuits along a route. This high crosstalk coupling also introduces another interesting problem in the control of amplifier gain, in that high level signals from the output of the amplifier, by cross induction into other pairs of the cable, are reintroduced into the pair connected to the input of the amplifier.

Shielded-Pair Video Cables

In order to overcome the limitations of regular telephone pairs and to provide greater flexibility in the use of the plant, shielded low-loss facilities, designed specially for video transmission, are now being introduced. Such special conductors can be provided most economically when they are included in full size cables along with other pairs provided to meet normal telephone requirements. To do this requires long range planning as telephone cables are generally designed to meet prospective requirements for a number of years.

The new shielded video facility now being installed consists of a balanced 16-gauge pair with polyethylene insulation. The transmission loss of this facility, also shown in Fig. 1, is about 18 db per mile at 4 mc. While initially circuits of this type will be equalized to 4 mc, the facility itself will not be a limitation in the transmission of much wider bands if the demand for such circuits should later materialize.

The impedance of the polyethylene insulated pair is such that it can be spliced directly to regular telephone cable pairs. It is thus possible to envision the ultimate development of a backbone television network of this type of facility reaching the most important television points in an area, to which regular telephone cable pairs can be connected to reach occasional service points. Fundamental studies looking to the orderly development of such networks are now under way in many cities.

One might ask why the use of coaxial structures is not contemplated in local areas. This type of structure is unbalanced and since local television transmission extends down to very low frequencies where the shielding is not effective, coaxial cable is susceptible to low-frequency noise induction and cross induction between adjacent coaxials within the same cable. In the intercity system, carrier methods put the line transmission at frequencies where the shielding can eliminate these effects. There are a few cases at present where coaxial cables are being employed for studio-transmitter circuits and are giving satisfactory service, but these circuits are short and well within the lengths at which it is possible to correct these effects.

Amplifiers and Equalizers

The amplifiers and equalizers now being used can accommodate line sections averaging as high as 60 db loss at 4 mc. Thus, depending on

the gauge of conductors available, amplifier spacings on regular telephone cable pairs will range from about 0.6 mile to about 1.5 miles for the types of cables usually encountered. In the case of the polyethylene-insulated video pair, amplifier spacings of about 3.5 miles are practicable. Because central office spacings sometimes exceed these lengths, it is necessary in some cases to use rented quarters as amplifier locations. This involves a number of special considerations such as finding suitable space near the desired location, ready access at all hours, power supply, and the like. The future design of video line amplifiers contemplates supplying power over separate cable pairs, which should simplify installations in rented quarters and make possible the installation of amplifiers in manholes.

The equalization of the line facility, including amplifiers and terminating equipment, involves the adjustment of the attenuation and phase characteristics over the desired transmission band. In wideband transmission systems of the type being discussed, it is practicable to design attenuation equalizers which also automatically correct for the phase deviations except in the regions near the edges of the band. Since the edges of the band are determined principally by the characteristics of the amplifiers and associated attenuation equalizers, the phase deviation is substantially independent of the length of line section between amplifiers. For this reason, a relatively simple fixed network in each amplifier (except the transmitting amplifier) provides the required phase correction and the field equalization job becomes one of adjusting only the attenuation over the desired band.

The line attenuation equalization is in the form of fixed units to provide basic equalization for various lengths of circuit. These are supplemented by two variable equalizers, one which corrects for slope by adjusting the loss at 4 mc with reference to the loss at 10 kc, and the other a bulge adjustment for varying the loss at 1 mc without substantial effect on the loss at 10 kc or 4 mc. A portion of the basic line equalization is provided at the output of the amplifier feeding the line section, the remainder being included in the amplifier terminating the line section. This pre-equalization improves the signal-to-noise ratio at higher video frequencies.

In order further to minimize the effects of noise, particularly on regular telephone cable pairs, predistortion is employed at the transmitting point which causes the 4-mc level to be 20 db higher than the 10-kc level. A complementary restoring network is used at the receiving end of the circuit.

Connection to Studio Equipment

Broadcasters' pick-up and studio equipments generally operate on an unbalanced basis. The amplifiers used to connect such equipment with the balanced telephone lines are shown in Fig. 2. Block diagrams of these amplifiers are shown in Fig. 3. Intermediate line amplifiers have both input and output balanced. Present plans contemplate that any switching or patching done in Telephone Company offices will be on a balanced circuit basis. A typical wire line video circuit, using regular telephone cable pairs and the amplifiers described, is shown in Fig. 4. Two frequency characteristics of such video circuits are shown in Fig. 5.

Microwave Radio

Radio facilities for short haul television circuits appear to have advantages for the occasional pick-up of a special news or sports event, and for unusual geographical situations, such as that between several studios in Hollywood and their proposed associated transmitters on Mount Wilson. In this latter case, wire video circuits would require a long and circuitous route with many amplifiers, whereas a single-link direct radio path can be obtained. Radio circuits at microwave frequencies need line-of-sight transmission paths, and in addition fading effects must be taken into account by allowing margins over the requirements for normal free space transmission conditions. Through the use of highly directive antennas, difficulties with interference and ghosts due to reflections can be minimized and low power can be used. The requirement for line-of-sight paths has in some cases resulted in a combination wire and radio circuit, the wire video facilities being employed to reach favorable radio transmitting or receiving sites.

Long Haul Coaxial Cable Systems

The search for increased efficiency in the use of conductors for multiplex telephony has resulted in the development of the coaxial cable system which is suitable for television transmission as well. The present standard coaxial unit, which has been used for installations since 1946, is 0.375 inches in diameter as compared to 0.27 inches for the earlier installations. The insulating discs supporting the central conductor are now of polyethylene rather than hard rubber previously used. The construction of coaxials and their arrangement in a typical cable are shown in the photograph. The coaxial itself does not limit the frequency range which

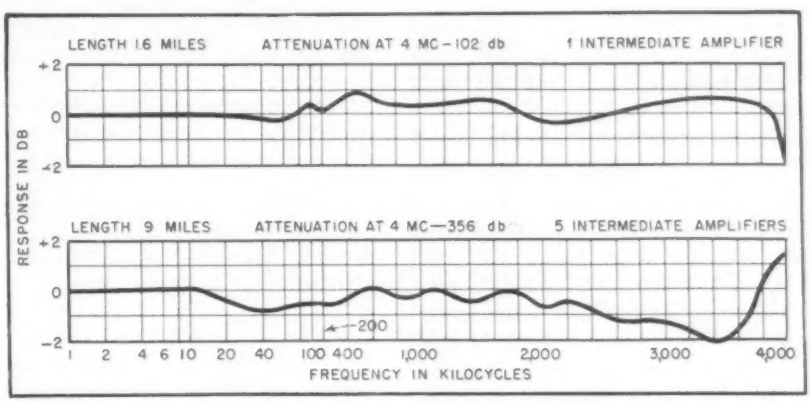


FIG. 5—Frequency characteristics for two video circuits of the type shown in Fig. 3

can be transmitted. This depends upon the bandwidth handled by the amplifiers and equalizers and the intervals at which they are placed.

The general layout of coaxial cable system is shown in Fig. 6. The present repeaters provide about 50 db gain at 3 mc and have a gain-frequency characteristic which very closely matches the cable loss characteristic. On the new 0.375-inch coaxials, these repeaters are spaced at intervals of about 8 miles whereas a spacing of about 5½ miles is used on the 0.27-inch coaxials.

Repeater stations are of two varieties, auxiliary and main. The majority of the stations are of the auxiliary type, the main stations being located at intervals of 40 to 165 miles. Most of these auxiliary repeaters are housed in small closed huts,* requiring no heat or power connections. The auxiliary repeaters operate from 60-cycle a-c power furnished over the central conductors of the coaxial from the main repeater stations.

For telephone use, terminals are provided for stacking 480 circuits in the 68-kc to 2,044-kc frequency space. It is proposed later on to operate additional short haul telephone circuits in the 2 to 3-mc band. For television transmission, the video signal, by a process of double modulation, is transmitted as an upper side band and a vestigial lower side band on a carrier of about 311 kc. The frequency space below about 200 kc is not used for television purposes because of the difficulties of equalizing this range and the less effective shielding provided by the coaxial structure at these frequencies. The associated sound channel is transmitted on a single-sideband basis between 76 and 88 kc. Transmission and phase characteristics of the 240-mile New York-Washington television circuit are shown in Fig. 7.

It is recognized that this television system provides a video band of about 2.8 mc instead of 4 mc provided for in the television channel assignment. Experience with this system has demonstrated that very acceptable pictures are being transmitted. Development work is continuing, however, on repeater equipment which will permit utilizing the coaxial structure to higher frequencies. One system considered employs closer repeater spacings than the present and would provide a usable frequency band of about 7 mc. This would permit the simultaneous transmission of about 500 telephone conversations and two oppositely directed 4-mc television programs on a pair of coaxials.

Service Protection Features

Many features have been included in the system to insure stability and continuity of service. Variations in transmission resulting from temperature and other changes are compensated automatically by regulators under control of four pilot frequencies—64 kc, 556 kc, 2064 kc and 3096 kc sent continuously from the main repeater stations over the coaxial line. The cables are generally buried deep in the earth or put in conduit, are protected against corrosion, lightning or mechanical damage, and are maintained under gas pressure with arrangements to detect any leak in the outer sheath so that repairs can be made before failures occur. Each stage of amplification in the repeaters has parallel tubes, and one tube in any stage can fail to function without interrupting service. Pilot alarms at each auxiliary repeater warn the nearest attended main station of excessive pilot deviations. The power supply is arranged so that if commercial power fails, a-c will automatically be supplied, through rectifier inverters or motor generators, from large storage batteries. Gas engines are available if the commercial power should be off for some time. Finally, a spare line is provided in each direction through each switching section, which may be up to 200 miles in length. Whenever a given coaxial line fails or its pilot gets out of limits, the spare line is automatically switched into the circuit so quickly that no interruption of any telephone conversation or television program occurs, and an alarm is given so that the trouble may be cleared.

Microwave Radio Relay

Wire communication is characterized by certain desirable features which have heretofore been lacking to a large extent in radio. For example, an unlimited number of channels can be established, the energy can be precisely directed, circuits can be made very stable, and noise and interference can be controlled. With the development of techniques permitting the use of frequencies of thousands of megacycles, radio is beginning to approach wire lines in these respects, permitting its extension over long distances by the use of repeaters, a method which has long been used for wire lines.

Experiments are now under way to determine the practicability of radio relay systems from the standpoints of cost, performance, and reliability. As a part of the Bell System experiments, a full-scale radio relay system is being established between New York and Boston. Preliminary indications are that satisfactory television operation could be provided by this means.

Seven intermediate radio repeater points will be employed, spaced at intervals of 10 to 35 miles, with an average spacing of 27 miles for a total circuit length of about 220 miles. These repeaters are located on high points of ground so that a direct line-of-sight path is available between adjacent repeaters.

In New York, the terminal is in

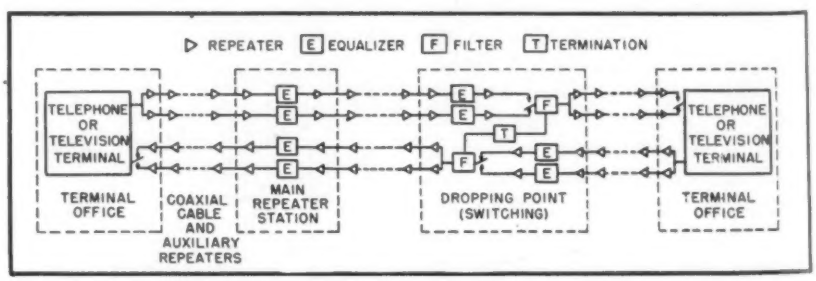


FIG. 6—An auxiliary parallel circuit in each direction is provided for emergency use in this layout of a typical coaxial system

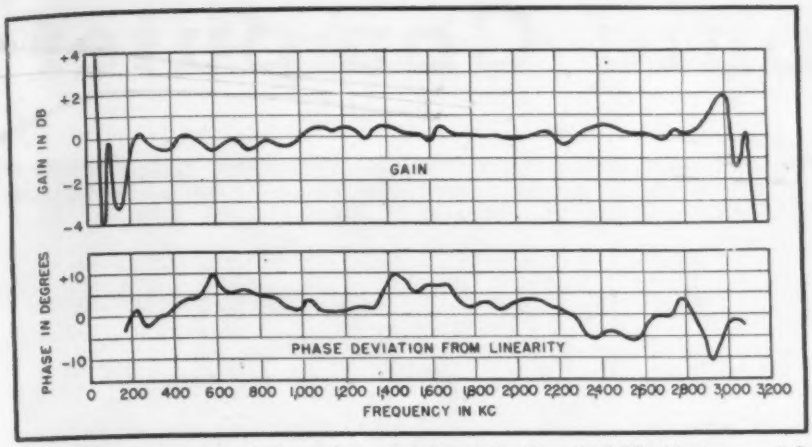


FIG. 7—Transmission and phase characteristics of the New York-Washington coaxial television circuit. Video bandwidth is limited to about 2.8 mc by the characteristics of the repeaters used

the long-distance building. In Boston, the radio terminal is about 1 mile from the main long-distance building with which it will be connected by short haul video facilities of the type discussed earlier.

The system will employ frequencies in the vicinity of 4,000 mc. A total of four channels will be established, two in each direction of transmission. Tests will be made on the transmission of large blocks of telephone circuits and of television. It is probable that a usable frequency band of at least 4 mc can be obtained for television transmission.

The antennas will be horns with 10-foot square apertures equipped with a metal lens to focus the radio waves. It is expected that a satisfactory signal-to-noise ratio can be obtained for the number of sections involved in this experiment using transmitting power in the order of 1 watt.

Recent Use of Television Circuits

A very considerable use has already been made of the television transmission facilities now available, particularly since the television broadcasting stations have been operating on a regularly scheduled basis. During the past year, some thirty short haul television circuits were established for one of more occasions of use, employing wire, experimental microwave radio or both in combination. The longest wire circuit—Yankee Stadium to Radio City—was about 9 miles in length and required the use of seven amplifiers. The longest radio circuit was one of two links between Michie Stadium at West Point and Radio City in New York, a distance of about 47 miles. In addition to those in New York, services were also established in Philadelphia, Baltimore, Washington, Pittsburgh, St. Louis and Los Angeles. Some of these channels have been continuously in service for several years.

A television circuit in coaxial cable arranged to transmit from Washington to New York was first used in connection with the Lincoln's Birthday ceremony on February 12, 1946. CBS, DuMont and NBC cooperated in arranging for the program which started with an introduction from the NBC studios in New York, after which a switch was made to Washington where pick-ups were successively made from the DuMont studio in the Harrington Hotel, the steps of the Capitol, and ceremonies at the Lincoln Memorial. By April 15, 1946, the New York-Washington coaxial cable was equipped for television transmission in both directions and was used by DuMont in connection with the opening of new studios in New York. Shortly afterwards, the two circuits between New York and Washington went into active use on practically a daily basis for the several broadcasters.

Further plans include the provision of shielded polyethylene-insulated video pairs in connection with cable construction programs in city areas to meet requirements for short haul television circuits quickly and economically. These plans are being carried out to the extent practicable with the scarce materials which can be allotted to this type of plant.

Great progress has been made in the construction of a nationwide coaxial cable network since the close of the war. As of January 1, 1947, about 4,000 route miles of coaxial cable had been placed in the ground and construction is continuing. Cables now in place or under construction and the extensions planned for the next three or four years total about 12,000 miles. It is expected that by early 1948 a southern coaxial cable route will be ready for telephone service to points as far west as Los Angeles, and that by the end of 1948 a central coaxial route will extend from New York to Chicago and St. Louis. Television service, if required, can probably be made available on most coaxial routes some time after the opening of telephone service, the date depending to some extent upon the demand.

In addition to the New York-Boston radio relay system, there is under construction a radio relay system between New York and Philadelphia, utilizing four links in tandem of a simplified type of equipment. Plans have also been projected for establishing a New York-Chicago radio relay system for multichannel telephone and television transmission. This is expected to be available by about 1950.

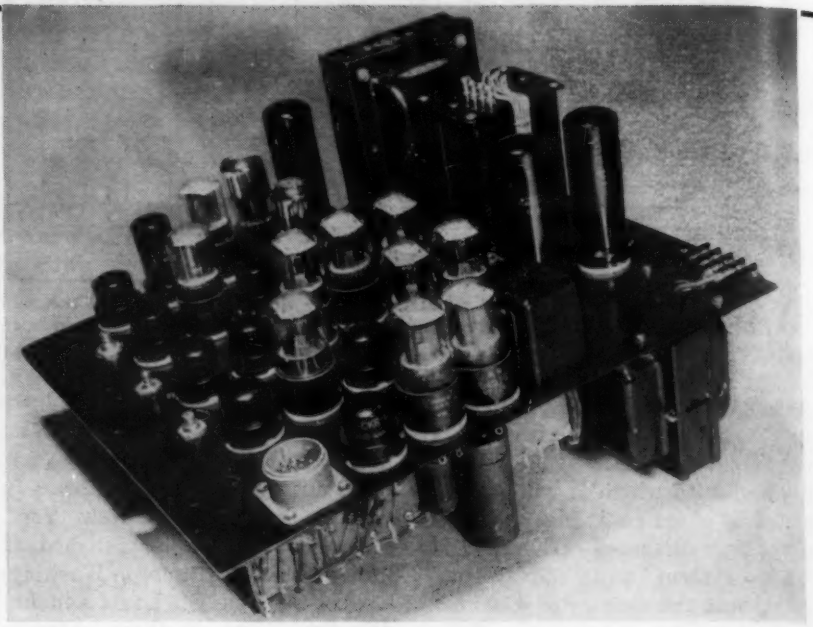
Future Prospects

The trend to wider and wider frequency bands, no doubt, will continue. These wider bands will be needed to handle the ever increasing demand for telephone communications and, perhaps, for greater definition or color television. Wider band circuits such as the 7-mc coaxial system discussed earlier are already under development by the Bell System. Still further in the future is the possibility of using long wave guides which are merely hollow tubes without central conductors and which provide transmission paths for enormously wider bands sealed away from interference of all sorts. It is quite clear that the future holds promise for advances far beyond the present status.

Electronic Computer

By JOHN W. LUDWIG

Vice-President
Electronic Control Corporation
Brooklyn, New York



Each 24-tube control amplifier that feeds a Diehl motor contains eight 6H6 tubes used to sharpen and clean the pulse caused by a registration mark to a width of less than 20 microseconds. This is necessary to distinguish the pulse caused by a registration mark from that caused by irregular reflections from the web of metal foil

THE OUTSTANDING industrial feature of electronic controls is their ability to "think" much as a trained operator thinks, that is, to anticipate changes in the process under control from experience and introduce corrections in time to prevent the state of the process from leaving the control point by a large amount.

Computing equipment with rate and acceleration elements has this anticipatory feature. It sees a rate of accumulation of error, or even its derivative, and begins corrective action long before the process has left the control point by an appreciable amount.

Large mathematical computers are not suitable either from a cost or equipment standpoint, for the great and ever increasing number of industrial control problems. Smaller equipment which, to a limited extent, can perform their functions are, on the other hand, in demand, particularly at present when increased productivity with higher quality from existing plants is a primary engineering problem.

Ideal Industrial Control

The following is a good set of general specifications for industrial control equipment: It must be infinitely superior in function to manual control on a cost or quality of product basis. It must give long periods of service with little attention and should not require special, on-the-job, maintenance personnel. It must be rugged, so as to stand general factory use and in a large number of instances it must be explosion or oil proof. It must be fairly high power (for control) equipment, say ½ horsepower to 50 horsepower. It must not set up unexpected stresses in the machines to which attached, therefore accelerations must be accurately controlled, and it must function under the vibration conditions of the equipment it is controlling. Preferably, it should be built to fit the job, of standard components, so as to make service and replacement easy.

It is the writer's opinion after six years experience in several fields

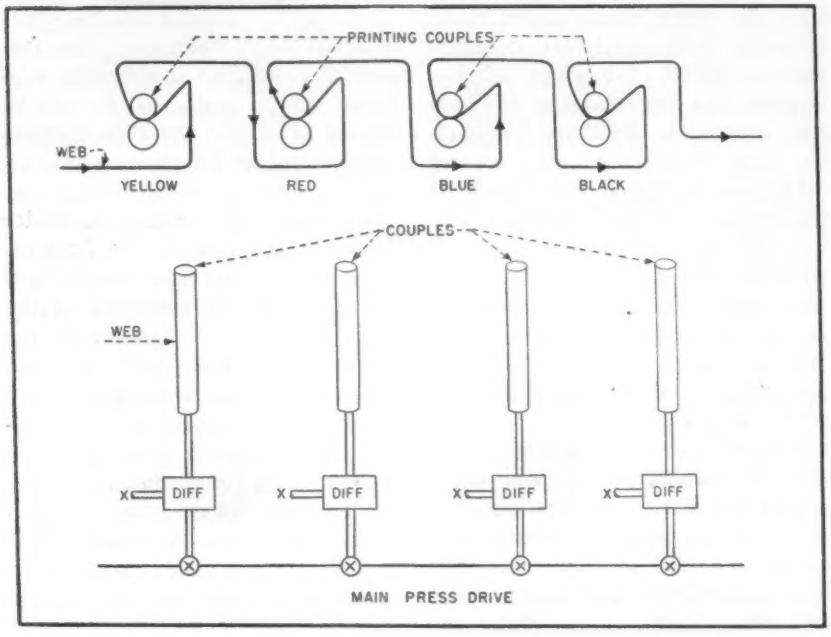
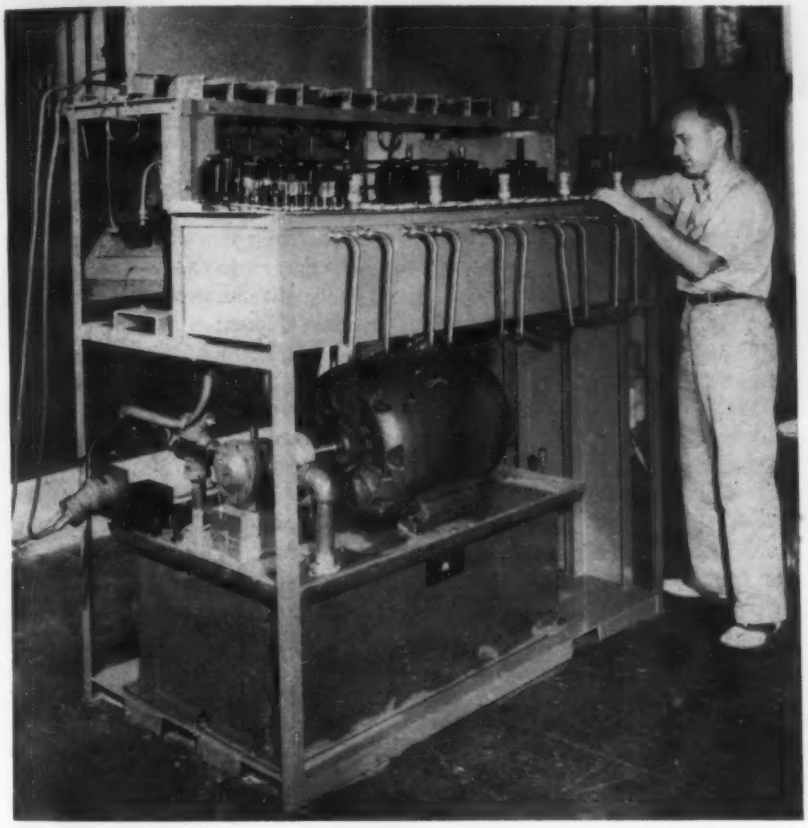


FIG 1.—Schematic views of mechanical arrangement of printing couples used in multicolor web. For register control, correction is applied to the differential systems at points marked X

for Printing Control

Speed of a multicolor web printing press is tripled by application of an electronic-hydraulic system that holds running register accurate from zero to 0.001 inch. Register marks actuate a phototube whose output is compared with a sample of a sine wave taken at the same instant



Complete setup of electronic and hydraulic units that connect to the printing press. Five 24-tube chassis are being immersed in oil inside the long steel box in which they normally operate

with industrial equipment that nearly all these specifications can, in general, best be met with a combination electronic-hydraulic system. For example, a hydraulic motor, which is a device which converts oil pressure and flow into continuous rotary motion, can be obtained which can deliver 10 horsepower and is 4 inches in diameter and 8 inches long with a moment of inertia of the rotating parts of only 13 lb-in.^{2} Hydraulic preamplifier valves can be obtained which require negligible torque and only 0.080-inch movement to control the hydraulic motor from zero to maximum horsepower in either direction.

Components such as these furnish their own lubrication, are explosion proof, give long periods of service, and are not adversely affected by the vibration usually encountered. Their use enables the use of low-power electronic apparatus of about 25 watts which can be made very reliable.

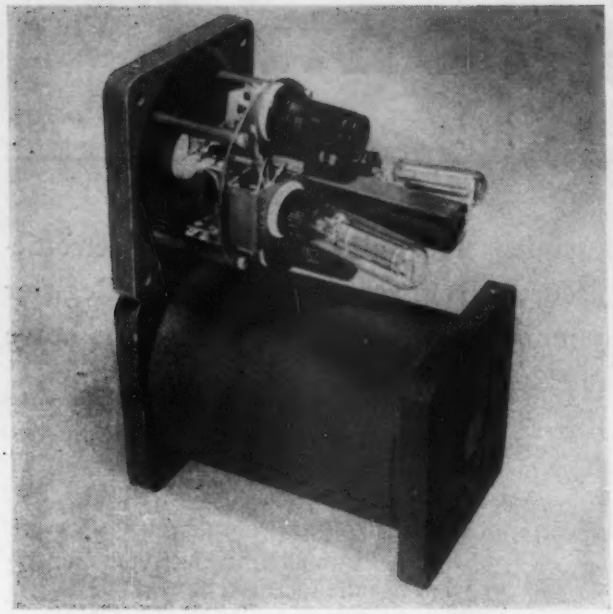
By combining electronic and hydraulic means it is possible to use low-power electronic equipment (usually without gas tubes in the control circuits) whose components are well standardized, long lived, reliable, easily obtained and relatively inexpensive. Hydraulic final actuating elements offer the advantages of high power with low inertia and small size, rapid response, and intrinsic explosion and oil proofing.

Delays which occur in the hydraulic system can be largely compensated in the electronic equipment. The electronic stages are flexible in that their performance can be varied without the necessity for major mechanical changes.

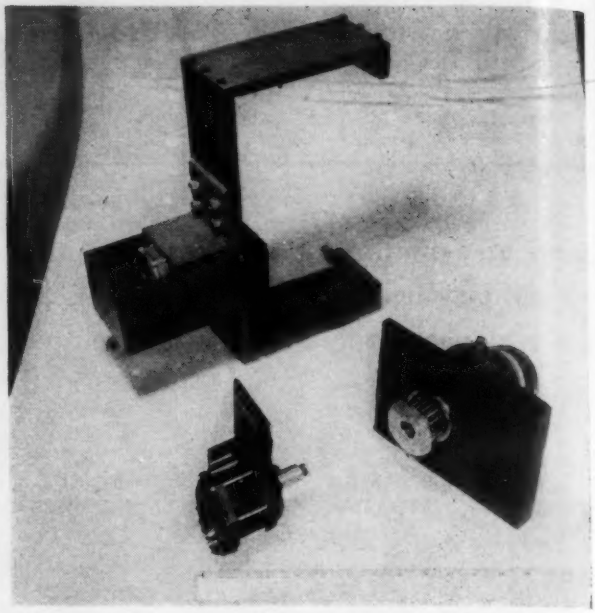
Typical Application

The problem to be discussed here was the design of running register controlling equipment that would enable a multicolor, roll fed, printing press to be stepped up in speed from 300 feet per minute to 1,000 feet per minute and still keep the register accurate from 0.000 to ±0.001 inch. The control decided upon drives into the press through a planetary gear system with a reduction of approximately 800-1 and had to be capable of continuous rotation in either direction.

Among the major problems in high speed color-printing are running or longitudinal register, lateral register, ink flow, and ink drying. Satisfactory solutions to the last two have been developed for today's press speeds and of the first two running register is the big problem, because sideways move-



The pickup head and explosion-proof housing are mounted on the press. It contains two phototubes and two amplifier tubes so that if one set fails, the other set is switched into the circuit



Sinewave p-m generator at lower left, ten-horsepower hydraulic motor at right, and induction generator for tachometer feedback at top

ments of the web are very small. The problem of running register can be explained by Fig. 1.

As the web travels through the press, it is important that each succeeding color be printed to the same baseline as the yellow, or the completed picture will be out of register, that is, one or more of the colors will be shifted with respect to the yellow. The register is maintained by scanning the web and controlling the X member of the differential which is inserted in the drive system of the press between each printing couple and the main drive. At present, running register cannot be accurately enough controlled for precision printing jobs at the high press speeds at which the other problems have been conquered, therefore the development of register-controlling equipment has been one of the industry's greatest needs.

Inasmuch as it would operate in an explosive atmosphere an additional requirement was that the control equipment meet the Underwriters Laboratories requirements for equipment in hazardous locations, Class I, Group D. These requirements in general specify that explosive atmosphere be prevented from reaching the equipment by immersing it in oil or that the equipment be encased strongly and tightly enough so that should an explosion occur within the case no effects of the explosion can reach the surrounding atmosphere.

Other requirements were that the control have a minimum of oscillation as that would cause excessive wear on the printing cylinder, and that the corrective action not take place so rapidly that excessive stresses were set up in the paper, metal foil, or cloth web being printed. (The web is the actual material being printed, not a conveyor for the material.)

The limits of automatic control were to be from 100 ft per min to 1,000 ft per min web speed. It is interesting to note that the problem of control became easier as the speed increased. If it had been possible to ignore such factors as web-strength, press design, ink-drying speed, and ink-flow characteristics, the maximum web speed could have been increased several times without decreasing the effectiveness of the control. The printing cylinder was 7 inches in diameter, thus the press varied from 54.5 to 545 rpm.

Measurements and calculations determined the inertia and friction torque characteristics of the press. The torque of the actuating element necessary to introduce the maximum correction in the time decided —approximately 0.15 second—figured out to be approximately 25 lb in. This relatively high torque requirement, coupled with the high speed of response needed, lead early in the design to the choice of piston-type hydraulic motors for the actuating element.

The problem of controlling electronically the power required for an electric motor developing the above stalled torque would present certain difficulties because of the need for high speed of response, the desirability of eliminating gas tubes in the control circuit, and the explosion-proof requirement.

The hydraulic motor, a Vickers MF-12-2, is controlled by an Askania standard regulator which is stroked by a Diehl two-phase motor type FPE-49-10 with a positive coupling whose rotor is allowed to turn only $\pm$ 1 degree. The electronic amplifier controls one phase of this motor and the power requirement is 25 volt amperes. This power is easily handled by components of the radio and telephone class and that is what was used.

Hydraulic power is furnished by a standard Vickers unit comprising a vane pump, explosion-proof drive motor, reservoir, and relief valve. The system pressure is approximately 200-250 psi.

Electronics in Oil

To meet the Underwriters specifications it was decided to immerse all electronic control elements in oil. To this end, a test program was un-

dertaken and the effect of immersion in transformer oil studied on sine wave generators, induction generators, two-phase motors, potentiometers, wire, vacuum tubes, capacitors, sockets, and terminal strips. These tests were conducted over a four-month period and as a result it was possible to obtain all necessary components as standard items which would satisfy the oil immersion requirement.

With the exception of the phototube scanning head, all apparatus is immersed in oil, the electronic components in transformer oil and the hydraulic components in their own oil supply. All connections to the press and between units are made through oil or pitch-filled tubing. Necessary controls are brought out above the oil level in all units or are accessible from above the oil with screw drivers or wrenches. The scanning head is made to meet the requirements for air-break explosion-proof gear.

The electronic amplifiers are all immersed to a depth of one inch over the tops of the tubes in a common oil bath and the leads brought out in copper tubing which starts well below the oil level. The electrical units, an induction generator and a permanent magnet generator are mounted on the press, and each is immersed in an oil tank and the leads brought out through oil-filled copper tubing.

The control amplifier is a d-c amplifier whose output is used to modulate the 60-cycle supply voltage for the control phase of the torque motor through a phase-sensitive modulator. The input to the amplifier is the error voltage obtained by sampling the voltage generated by the permanent magnet generator coupled to the printing cylinder at every register mark interval.

The voltage on the sine wave at each sampling instant is clamped,[1] then filtered into a smooth wave which serves as the input to the control amplifier. This error signal is differentiated to reduce dynamic errors and integrated to reduce accumulative errors.

Tachometer feed back, proportional to the rpm of the correction motor, is used to check that the correction motor is faithfully following the designed function of input signal. An induction generator geared to the hydraulic motor furnishes this feedback.

The time to introduce a correction should the web be subjected to a step function between register marks, rather than the usual error change, would, of course, be greater; but it would still be far shorter than can be accomplished by manual control (which, to date, has been the most universally satisfactory method) since the control will see the error at the next printing station and will start correction immediately rather than waiting until the affected section of web has left the press.

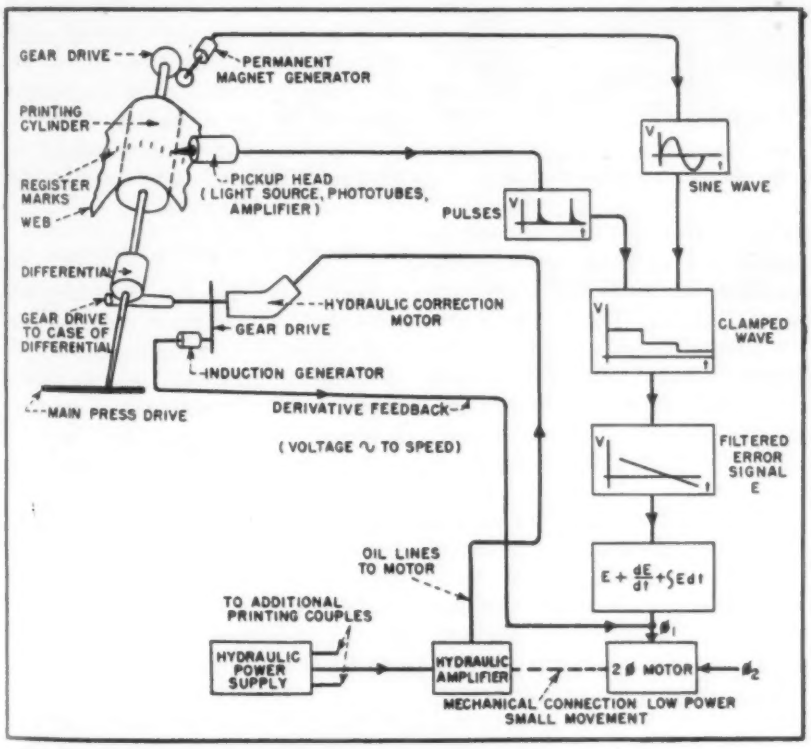


FIG. 2.—Schematic of the register control system. Functions of the electronic stages are illustrated in blocks at right

Constant Performance

The gain of the control amplifier and its frequency characteristics are fixed, to assure constant performance of the control even though the operating conditions change. Detailed measurements and calculations of the inertia and friction forces in the press and of the torque characteristics of the actuating means were made and the stability of the system was investigated. In the present case an ample margin of stability does exist provided the delays in the hydraulic system are compensated. Provision for such compensation is included in the electronic amplifier.

A schematic of the entire system is shown in Fig. 2. Provision is made for returning each roll individually to manual control if the error signal from that roll exceeds a preset value for more than a given time, thus indicating that that control is not functioning properly.

Labor Upgrading Effect

A control such as the one described has an upgrading effect on highly skilled labor. A pressman's production is tripled. He is removed from the negative, routine task of register control and applied to more technical ones such as ink color and flow, drying, printing pressure. In this way his position becomes more important at the same time that he becomes more productive.

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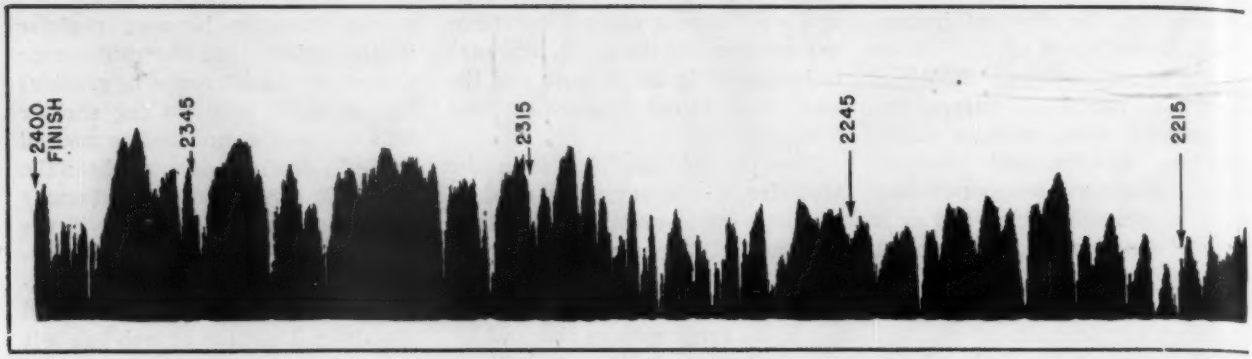
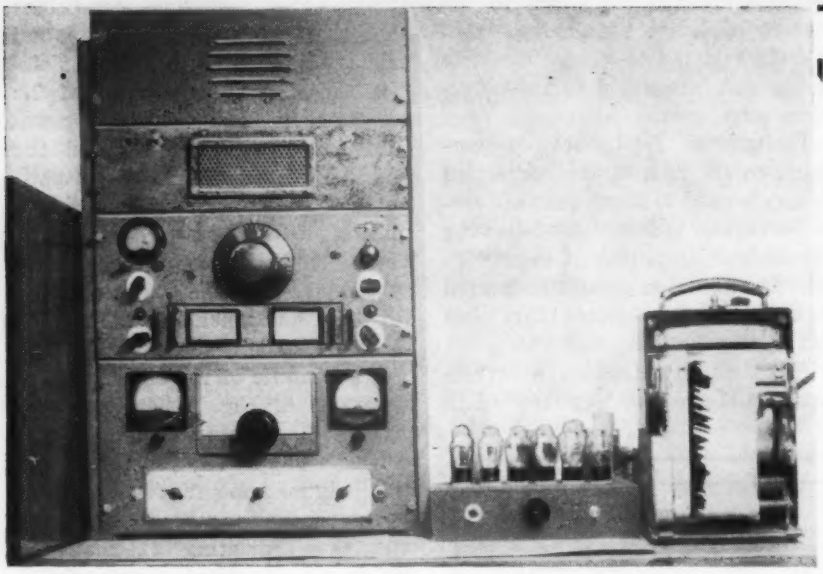


Example of strip chart obtained with sky-wave signal recording equipment at Strathburn, Ontario. Curve shows variation in input signal strength to receiver over period of several hours at night for signals of station WGY, Schenectady, N. Y.

Recording Sky-Wave Signals



Receiving rack, cycler chassis, and graphical recorder used at Ottawa frequency monitoring station for recording sky-wave signals from broadcast stations

By WILBERT B. SMITH

Assistant Radio Engineer, Radio Division Department of Transport, Ottawa, Ontario, Canada

A GOOD DEAL of the energy radiated from standard-band broadcasting stations is reflected from the ionosphere and returns to earth at a distance from the station. This phenomenon is an advantage in the case of clear-channel stations since it augments the coverage, but where channels are shared by two or more stations in the same region it may produce interference which seriously limits the coverage otherwise obtainable.

In the broadcast allocation structure, due cognizance must be taken of the effects of sky-wave signals. Ground-wave propagation is calculated from verified theoretical curves, but because of the many indeterminable factors involved in sky-wave propagation, no corresponding curves exist, and calculations must be made from entirely empirical curves. These curves are plotted from measured data on the sky-wave signal intensities of distant stations over an extended period, and are based on the signal exceeded for certain percentages of time.

Early curves took no separate account of variations due to latitude, or between north-south and east-west propagation, or of ionospheric focusing, but assumed an average propagation characteristic for all sky-wave signals. The early curves are the ones which have been in use up to the present time, under the North American Regional Broadcasting Agreement, Havana, 1937.

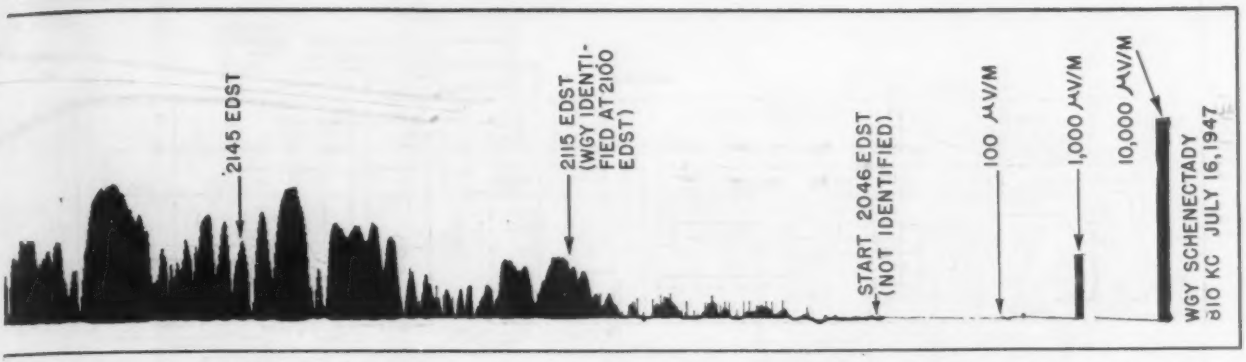
The Modus Vivendi, Washington, 1946, which extends the above-mentioned agreement, recognized the need for more up-to-date information on which to base new technical standards to be drafted in 1948, and charged the signatory countries with making the necessary studies towards this end. A program of sky-wave recording was therefore drafted by the Canadian authorities to determine the propagation characteristics of sky-wave signals in Canadian latitudes.

Sky-Wave Recording Technique

Equipment for the recording of sky-wave signals must be accurate and stable, yet simple enough to be used in outlying stations. It must produce records which are readily analysed in terms of the absolute field intensity of the radio wave, in microvolts per meter.

The essential components of field-intensity recording equipment are the radio receiver and antenna, comparison standard signal generator or other calibration means, and the graphical recorder.

In the system as finally developed by the author for the Canadian recording program, the incoming signal is received on a National HRO



Analysis of above chart with photoelectric scanner showed that signal exceeded 6,100 μv 5% of the time, 5,300 μv 10%, 3,000 μv 30%, 1,700 μv 50%, 1,400 μv 60%, 820 μv 90%, and exceeded 700 μv 95% of the time

from Broadcast Stations

Description of monitoring station set up by Canadian government to investigate sky-wave interference occurring when two or more broadcast stations share the same channel. Signal strength of a station is recorded on strip chart for several hours, and photoelectric scanner then determines percent of time signal exceeds any selected value

receiver which has been peaked for maximum i-f response, and from which the avc voltage is fed to a vacuum-tube amplifier which drives a 5-ma graphical recorder. In series with the graphical recorder is a device which periodically returns the recorder pen to zero so as to blank in the area between the curve and zero to facilitate analysis of the graphs. The incoming signal as delivered by the antenna is compared with the output of a standard signal generator for calibration of receiver output. The antenna itself is calibrated by comparison with a field-strength meter of known accuracy.

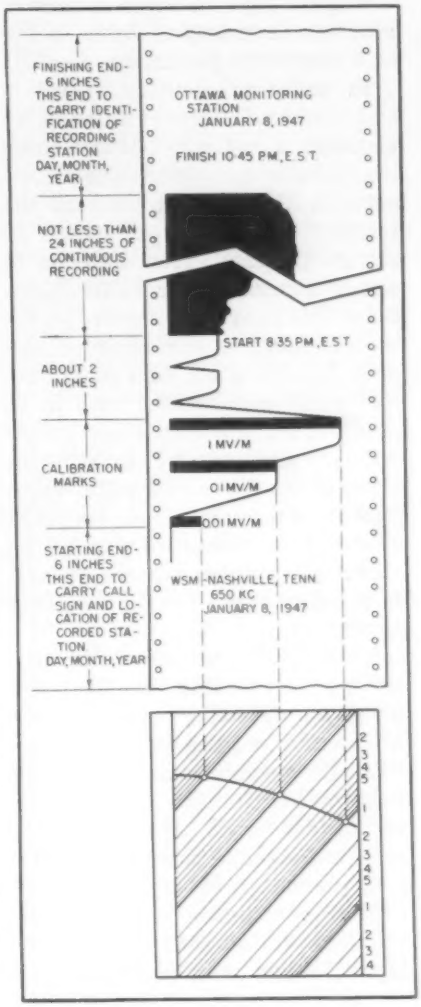
Analysis of the charts is accomplished by means of an electronic scanner, in which a spot of light rapidly traverses the chart along the time scale. The reflected light operates, through a phototube and amplifier, an electronic gate which permits current to flow through a meter calibrated directly in percentage only during the periods when the spot is on the blanked-in portion of the chart. In this manner the scanner integrates the time during which a particular value of signal was exceeded. Suitable scales used in conjunction with calibration marks placed on the charts permit direct determination of the field intensity exceeded for any specified percentage of time.

Signal Generator

The circuit diagram of the standard signal generator is shown in Fig. 1. It is a straightforward design, the only unique features being the shielding, the use of a coupling tube between the r-f sources and the receiver, and the vacuum-tube voltmeter circuit.

Effective shielding is achieved by locating the oscillator and the circuits associated with it in individual cast aluminum boxes which are insulated from ground, connected together in sequence at one point only, and grounded to the main chassis at one point only. Circuits entering the boxes are individually filtered by means of chokes and capacitors, and control shafts entering the boxes are broken with insulated couplings. Circuits within the box are grounded at one point only, near where the r-f voltages are finally delivered.

Under the provisions of present


FINISHING END-6 INCHES THIS END TO CARRY IDENTIFICATION OF RECORDING STATION DAY, MONTH, YEAR
NOT LESS THAN 24 INCHES OF CONTINUOUS RECORDING
ABOUT 2 INCHES
CALIBRATION MARKS
STARTING END-6 INCHES THIS END TO CARRY CALL SIGN AND LOCATION OF RECORDED STATION DAY, MONTH, YEAR
OTTAWA MONITORING STATION JANUARY 8, 1947
FINISH 10:45 PM, E.S.T.
START 8:35 PM, E.S.T.
1 MV/M
01 MV/M
001 MV/M
WSM-NASHVILLE, TENN. 650 KC JANUARY 8, 1947

Format followed in recording signal strength of broadcast station on strip chart, and (below chart) method of obtaining calibration curve used in connection with electronic scanner

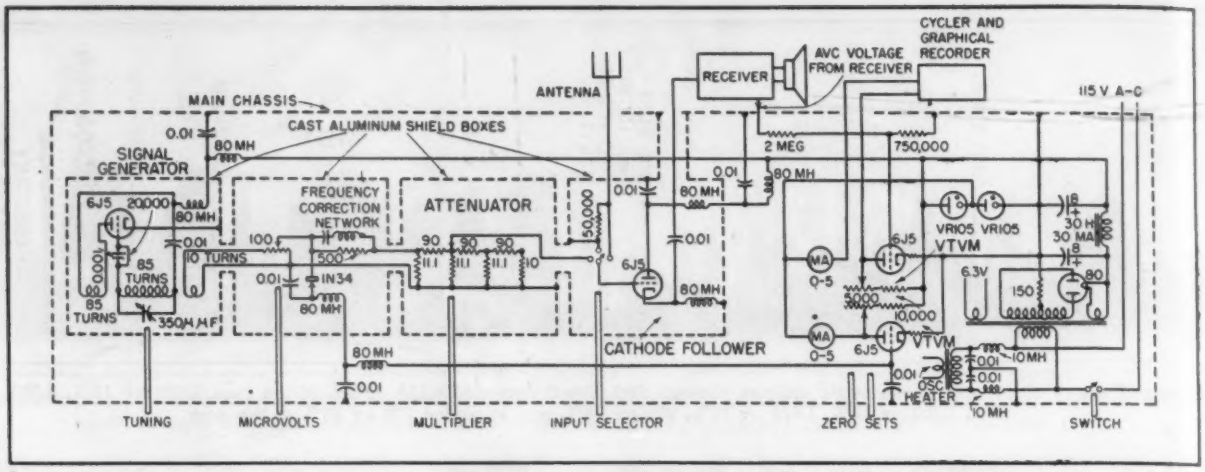


FIG. 1—Circuit of signal generator used for calibration in connection with recording of sky-wave signals, showing elaborate shielding technique employed and relationship to other units of recording system

international agreements the lowest sky-wave field which has any significance is 25 microvolts per meter, so there is little advantage in making studies on field intensities much less than this. Therefore the signal generator was designed to deliver calibrated r-f voltages only down to 10 microvolts, which with the usual broadcast type of antenna permits accurate recording of fields as low as 5 microvolts per meter.

In order to simplify operation and minimize effects of antenna variations, a cathode-follower coupling tube is included in the circuit between the r-f sources and the receiver input, with a switch to change the input from antenna to signal generator for calibrations. Since this tube is in the circuit for both calibration and recorded signals, it is in effect part of the receiver and is calibrated with it. It does not introduce spurious effects unless subjected to r-f signal intensities of the order of 2 volts, which may drive the tube beyond its range of linearity. Localities where high signal strength exists are avoided in selecting a site for the recording equipment.

Two similar vacuum-tube voltmeters are provided, one for measuring the r-f voltage applied to the attenuator, and the other for operating the graphic recorder from the received avc voltage. They consist of triodes with the indicating meters bridged between their plates and the midpoint of two voltage regulators in series. The tubes are operated under conditions of no input voltage with about 0.8 volt

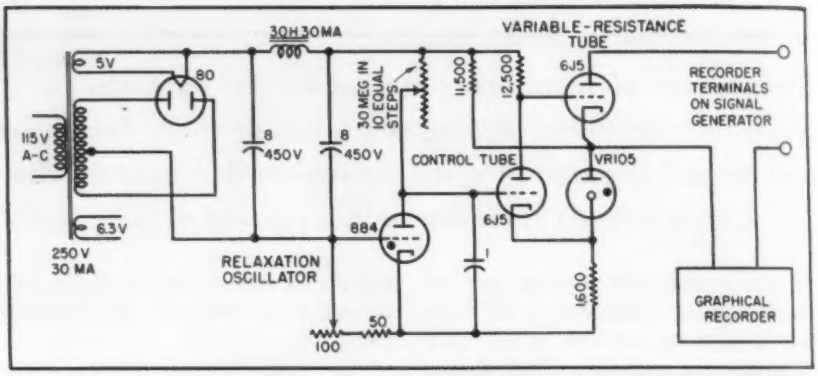


FIG. 2—Cycler circuit for sweeping pen of recorder periodically back to zero, to black in entire area between signal strength curve and zero. Rate of sweep may be varied from once per second to once every 5 seconds by adjusting 30-megohm resistor

bias, obtained from a cathode resistor. The plate resistances are varied for zero reading on the respective meters, as zero-sets. For any negative voltage applied to the triode grid, the plate current will decrease a proportionate amount over the corresponding portion of the tube characteristic, which in the case of the 6J5 triodes is quite linear. The change in plate current will result in the difference current flowing through the meter, giving after calibration the measure of the applied voltage.

Provides Protection

This circuit was selected to utilize the negative avc voltage from the receiver, and to provide protection against accidental overload of the meters or recorder from excessive input voltage. Excessive input voltage can only drive the triode to cutoff, when the meter will be called upon to carry not more than the normal plate current of the triode, which is approximately 8 ma and not dangerous for a 5-ma meter.

The vacuum-tube voltmeter which reads the r-f voltage applied to the attenuator obtains its grid voltage from a germanium crystal rectifier. No return resistance path is provided for this rectified voltage as the germanium rectifier itself has a sufficiently low resistance in the reverse direction to permit the grid charge to leak off. Since the voltage applied to the tube grid is very nearly equal to the peak value of the r-f voltage applied to the attenuator, the original calibration of the signal generator can be against a standard cell, although comparison against a laboratory standard signal generator may be more convenient.

The second vacuum-tube voltmeter obtains its grid voltage from potential-dividing resistances across the avc circuit of the receiver. The values of these resistances are such as to bring the range

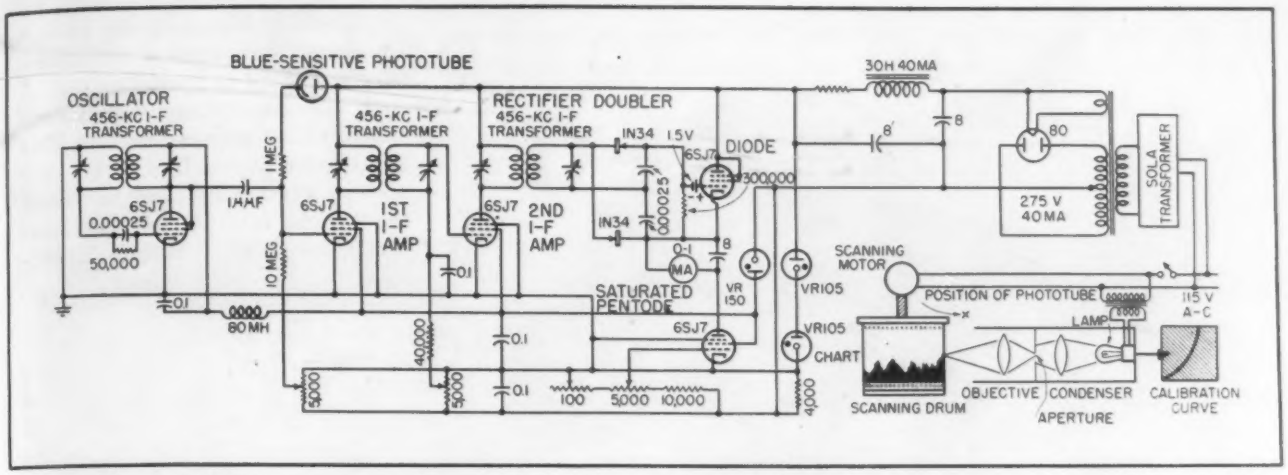


FIG. 3—Circuit of electronic scanner used for analysis of charts. Arrangement of optical system is shown at lower right; phototube is mounted on carriage along with lenses and lamp, and picks up light reflected from spot on chart

of the meter onto the portion of the receiver gain characteristic which is most nearly logarithmic. It is therefore possible to get better than two complete ranges, or a ratio of 100:1 within the scale of 0-5 ma, using a National HRO receiver.

Chart-Blanking Circuit

The circuit for blanking in the area on the chart between the curve and the zero for analysis by means of an electronic scanner is shown in Fig. 2. Electrically it consists of a small resistance in series with the graphical recorder, which resistance remains constant for about four-fifths of the cycle, and then increases to infinity over the remaining fifth, after which it suddenly returns to its previous value and the cycle starts over again.

The resistance which performs in this unusual manner is the plate resistance of a 6J5 triode, the grid of which is held about 4 volts positive for the first four-fifths of the cycle. Under these conditions the tube shows a linear plate resistance characteristic of about 300 ohms for currents as high as 8 ma.

The grid of the output or variable-resistance tube is connected to the plate of another 6J5 triode which acts as a control tube to translate the voltage developed by the relaxation oscillator into an increasing bias. Since the control tube is biased well beyond cutoff for four-fifths of the cycle developed by the relaxation oscillator, it does not come into action until the last fifth of the cycle. It then diverts the current previously flowing through the grid circuit of the output tube, permitting the bias of that element to increase to cutoff.

The relaxation oscillator is conventional, being a capacitor charged through a high resistance and discharged through a type 884 thyratron. By using a tapped 30-megohm resistance and a 1-μf oil-filled paper capacitor, good stability was obtained with periods from 1 to 5 seconds long.

For chart speeds of 1 foot per hour the 5-second period is required, but for faster speeds a correspondingly faster rate applies.

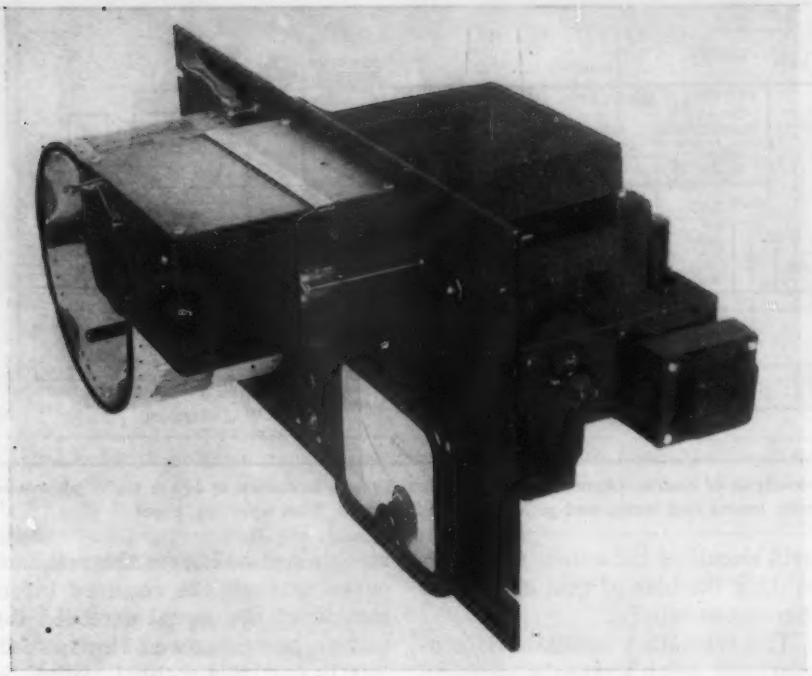
An Evershed-Vignoles graphical recorder with 5-ma range and clockwork drive is used. This instrument is fitted with an oil dashpot so that control can be had over damping, which is important for the cyclic operation to which the instrument must respond. Wrinkling of paper was overcome by using No-Rinkle ink and Albanene paper produced by Keuffel & Esser. The combination of a red ink and a blue-sensitive phototube in the electronic scanner was found to give best results.

Electronic Scanner

A substantial part of the information to be gleaned from the chart is statistical and involves the determination of the signal exceeded for certain percentages of time, during certain periods relative to sunset. Heretofore, the method of analysis has been to step off with dividers and scales the time increments corresponding to certain signal intensities, replot the values so obtained and from the resultant curve read off the required information of the signal exceeded for certain percentages of time. Needless to say, this manual method is tedious and inefficient, and opens wide the door to personal error which it is almost impossible to check. Fortunately, however, when a great deal of data is so analyzed most of the errors balance out in the subsequent statistical mathematical treatment, but there still remains the tedious labor of the manual analysis.

The electronic scanner was developed for the dual purpose of speeding up analysis and eliminating largely the personal error. Due to the shortness of time during which the Canadian program could operate before the data would be required for the production of propagation curves, speed and accuracy of analysis were essential.

The circuit of the scanner is shown in Fig. 3. The chart to be scanned is wound around the scanning drum, which will accommodate 24 inches of chart for each operation. The lamp-house contains a carriage which slides along ways under the control of a crank on the front of the lamp-house. Mounted on this carriage is a light source consisting of a 32-candlepower automobile lamp, condenser lens, diaphragm with a 1-mil aperture, and an objective lens which focuses the image of the aperture as a small spot of light on the chart undergoing analysis. Also mounted on the carriage is a phototube so arranged as to pick up diffused reflected light



Electronic scanner unit used at Radio Standards Office in Ottawa for analysing sky-wave charts obtained with recording equipment. Logarithmic calibration chart is placed under pointer on table just above drum. Pointer is mechanically coupled to optical system

from the spot on the chart. The top of the lamp-house carries a special logarithmic graph under roughened plastic to take pencil lines. Crossing the chart is a pointer which is connected to the carriage and arranged to track with the position of the spot of light. The near side of the pointer acts as a straight edge to place the calibration lines on the graph, and to read off the values of signal exceeded.

The electronic section consists of an amplifier responsive to the standard i-f value of 456 kc but normally biased slightly beyond cutoff. This amplifier is supplied with 456-kc excitation from an oscillator through a small capacitor, but does not come into action until the bias on its first stage is reduced by illumination of the phototube. The output of the amplifier is rectified by two germanium rectifiers in a doubler circuit, and applied to the grid of a triode-connected 6SJ7, which is in series with a 6SJ7 saturation pentode and the percentage-of-time meter.

When the phototube is not illuminated there is no appreciable output from the amplifier and the grid of the triode is maintained at zero potential by a flashlight battery, permitting the full saturation current of 1 ma to flow through the saturation pentode and give a full-scale reading on the percentage-of-time meter. This condition corresponds to the scanning of a completely inked-in portion of a chart undergoing analysis.

When the phototube is illuminated the amplifier comes into action and produces at the output of the germanium rectifier 50 volts or more, which produces immediate cutoff of the triode. For the period when this condition prevails no current flows through the percentage-of-time meter. This corresponds to the scanning of a blank portion of the chart.

Since the percentage-of-time meter is of the uniform scale type, it will read the average current flowing through it, provided the cycle is fast enough to prevent the meter movement from following the individual fluctuations. Hence it follows that in the scanning operation the meter will read directly the percentage of time during which the phototube has not been illuminated, which is the percentage of time a certain signal strength has been exceeded.

The instrument can be made unresponsive to residual room illumination by judicious adjustment of the amplifier bias controls, so that no special precautions are necessary in regard to room lighting. A Sola constant-voltage transformer supplies the electronic circuits. This transformer combined with the voltage regulators used to obtain the various internal voltages gives maximum stability and the instrument can be easily read to an accuracy within 1 percent.

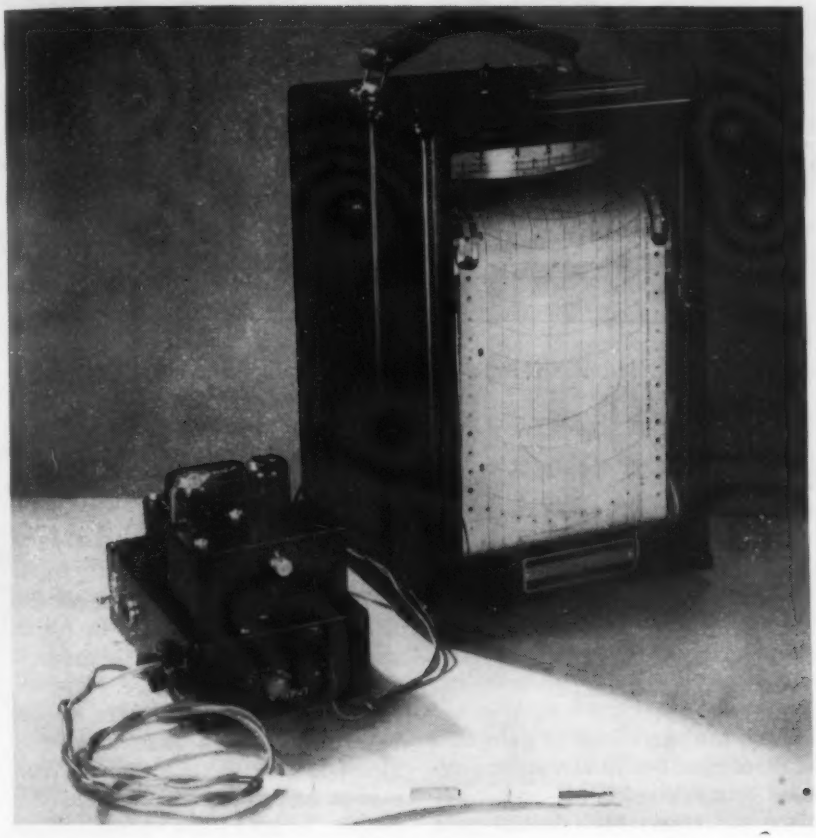
The image of the aperture in the diaphragm on the chart being scanned is about 0.03 inch in diameter, which is about the width of the line traced by the pen on the graphical recorder. Consequently, the scanner can resolve and analyse any record normally taken by the recorder. The accuracy with which the percentage-of-time meter and the calibration on the graph can be read is about 2 percent.

In using the scanner, the chart to be analysed is first placed on the drum with the zero side to the front and with the calibration marks showing on the outside. The pointer is then wound successively to the top of each calibration mark and a short pencil line drawn along the straight-edge intersecting an appropriate unit line on the graph. These points are then joined up by a smooth curve which provides the scale from which signal intensities pertaining to that particular chart are read. The curve so plotted is in reality the received signal versus avc voltage curve, and consequently provides the means for reading directly in microvolts per meter the field intensity from the recorded values of the resultant avc voltage. A new curve is drawn for each chart analysed.

After the calibration curve is established, the chart is moved around the drum until the portion of which the analysis is desired is on the outside and visible to the scanning spot. The drum is then started rotating and the percentage-of-time meter checked for zero and full scale. The scanning spot with its attendant pointer is then wound across the chart until the meter reads the desired percentage of time, when the corresponding field intensity can be read off directly from the intersection of the straight edge of the pointer with the calibration curve.

Electromechanical D-C Amplifier

By C. G. ROPER
Chief Engineer
and
J. F. ENGELBERGER
Development Engineer
Electrical Engineering Department
Manning, Maxwell, and Moore, Inc.
Bridgeport, Connecticut



Small chassis at left contains the d-c amplifier and power supply used with the recorder and thermocouple (bottom) to measure transients in a thermal process

APPLICATIONS

Production matching of resistors. Gives quick response with high sensitivity to replace galvanometer
Experimental production of thermocouples. Used with recorder to measure time response characteristic of thermocouple element
Development of temperature regulators to drive transient response recorder
Serves as power or impedance changer to make possible long distance transmission or telemetering of low level d-c signals
Amplify outputs of barrier layer photocells, Pirani or ionization-type vacuum gages
Amplifier for control equipment, and servomechanisms
Bridge detector
Preamplifier in radiometry recording

A moving-coil system actuates a metal flag in an oscillator tank to provide high gain and stable d-c amplification. Operating principle, mechanical details, and circuits of a degenerative system for low-impedance, low-current inputs are given

WHOLLY ELECTRONIC d-c amplifiers are subject to drift resulting from supply voltage variation, tube characteristic instability, and variations of temperature and humidity. Also, this type of amplifier does not lend itself to low-impedance inputs.

When voltage regulation and balanced circuits are used to reduce drift, the amplifier becomes complicated and unwieldy. For laboratory use this last point is perhaps no handicap, but for industrial and aircraft usage, complexity and size, not to mention cost, become vitally important.

The chopper type d-c amplifier, while it can be used with a low-impedance input, structurally is difficult and expensive to make. For many industrial purposes, as well as aircraft applications where space and weight are at a premium, it is inconvenient, and its extremely high gain is unnecessary.

Combination System

The principle of electromechanical d-c amplification is illustrated in Fig. 1.

In Fig. 1A, a low-level voltage input to a galvanometer is converted into motion, and this motion is then employed to tune an oscillator by having a metal flag move be-

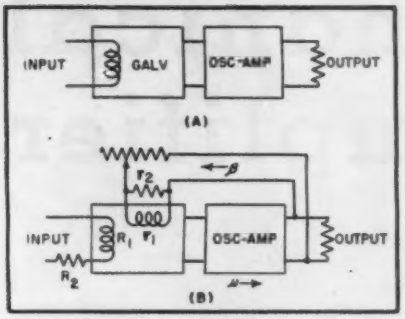


FIG 1—Basic principle of the electromechanical system is illustrated at (A). The method of adding feedback is shown at (B)

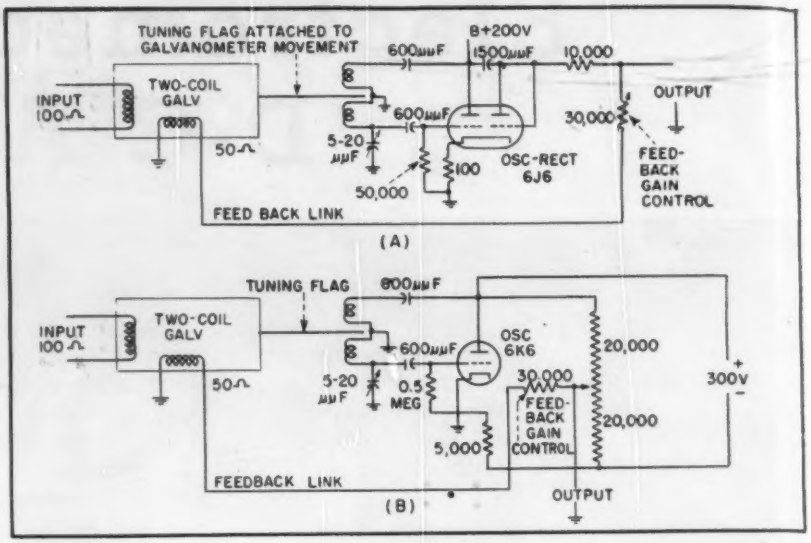


FIG. 2—Two practical circuits for using the current-sensitive tuning flag and an electronic oscillator to obtain amplification. Both provide a voltage gain of 1,000

tween coils of a tuned-grid, tuned-plate oscillator. The motion of the metal flag loads and unloads the tank circuits with consequent variation in input voltage of the oscillator. With a reasonably sensitive galvanometer movement, such a conventional setup can easily provide voltage gains higher than 10^6.

In Fig. 1B, an extra coil has been added to the galvanometer, and the output voltage is fed back to the galvanometer input. Basically, this is the complete d-c feedback amplifier. Feedback could be applied to the input coil, but the advantage of an isolated input would then be lost.

Since a galvanometer input is used, a low-impedance input offers no difficulties. So, too, this extremely high-gain mechanical input stage does away with input tube selection and fastidious care of operating conditions.

Considering the overall circuit, the gain of a feedback amplifier may be written as[1]

$$\frac{E_{\text{out}}}{E_{\text{in}}} = A = \frac{\mu}{1 - \mu\beta}$$

where A = gain of feedback amplifier, μ = forward gain without feedback and β = feedback fraction.

This can be rewritten as

$$A = \frac{-1}{\beta}\,\frac{1}{1 - 1/\mu\beta} \qquad (1)$$

Thus as long as the quantity $\mu\beta$ is large, A is practically equal to $-1/\beta$, and the gain is almost independent of changes in μ.

The actual reduction in gain variation as a result of change in μ may be computed as follows:

$$E_0 = \frac{\mu}{1 - \mu\beta} E_i$$

differentiating with respect to μ

$$\frac{\partial E_0}{\partial \mu} = E_i \frac{1 - \mu\beta + \mu\beta}{(1 - \mu\beta)^2}$$

$$= \frac{1 - \mu\beta}{\mu} E_0 \frac{1 - \mu\beta + \mu\beta}{(1 - \mu\beta)^2}$$

$$= \frac{E_0}{\mu(1 - \mu\beta)}$$

$$\text{or } \frac{\partial E_0}{E_0} = \frac{1}{1 - \mu\beta}\,\frac{\partial \mu}{\mu} \qquad (2)$$

Thus, the variations in gain as a result of changes in circuit are reduced by a ratio of $1/(1-\mu\beta)$.

The extremely high initial gain of this electromechanical d-c amplifier permits of large feedback factor $\mu\beta$ to reduce drift, while resultant gain which has been shown to be virtually equal to $1/\beta$ is still, for many purposes, quite satisfactory.

Faster Action

The feedback to the galvanometer is also advantageous from another point of view. The time response of the galvanometer is greatly improved; that is, the natural undamped period of such a mechanical system is reduced to a fraction of its original value.[2]

It can be shown that feedback in the galvanometer is given by,

$$C' = (1 + \mu\beta)C$$

where C = stiffness of suspension and C' = stiffness with feedback. Since the unclamped period of the galvanometer is given by,

$$\tau = 2\pi\sqrt{\frac{K}{C}}$$

where τ = period and K = moment of inertia then the period with feedback becomes,

$$\tau = 2\pi\sqrt{\frac{K}{C}} = 2\pi\sqrt{\frac{K}{\mu\beta C}}$$

Thus, feedback has reduced the period by a factor of $1\sqrt{\mu\beta}$.

Temperature Compensation

When the amplifier is used with a current input, change in resistance of the input coil with temperature is of no consequence. However, for a voltage input there is one other major advantage to be considered; that is the input circuit can be completely compensated for copper temperature error. This eliminates necessity for insulating the input circuit or for adding large zero temperature coefficient resistors in the input circuit.

The method of temperature compensation can be explained with reference to Fig. 1B. Both coils on the galvanometer movement are copper and, therefore, for any temperature change undergo the same percentage change of resistance.

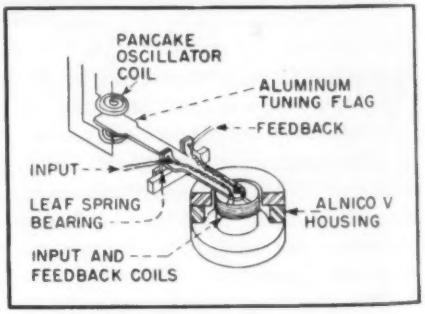


FIG. 3—Construction details of the galvanometer-type movement. The input and feedback coils are wound one above the other

Now when $\mu\beta$ is much greater than unity and the gain, A, is equal to $1/\beta$, the feedback current is directly proportional to output voltage. A zero temperature coefficient resistor, r_2, is placed across the feedback coil, r_1, to divide the feedback current; and this division of current varies as the resistance of the copper feedback coil changes.

On the input side, R_2 is placed in series with R_1, the copper input coil, and changes in the resistance of R_1 result in changes of input current. It can be shown that with change in resistance of the two copper coils, the percentage change of current through the input coil is exactly equal to the percentage change of current in the feedback coil if $R_1/R_2 = r_1/r_2$. Thus loss of input sensitivity is balanced by a decrease in β, the feedback fraction, and the gain remains constant as the temperature changes. Since the ratio r_1/r_2 can be made as small as the feedback power available will allow, the ratio, R_1/R_2, which also represents loss of gain as a result of compensation, can be kept correspondingly small.

In general, two convenient possibilities for the circuit of the amplifier have been tested. They are shown schematically in Fig. 2. In Fig. 2A, the r-f oscillator output is rectified to provide d-c output and feedback current. In Fig. 2B, the change in the d-c impedance of the oscillator tube with strength of oscillation is employed to unbalance a bridge. It is worthy of note that frequency variation is not considered in either of these methods and that one need not be concerned with exact frequency stabilization. Only the magnitude of the r-f signal is significant.

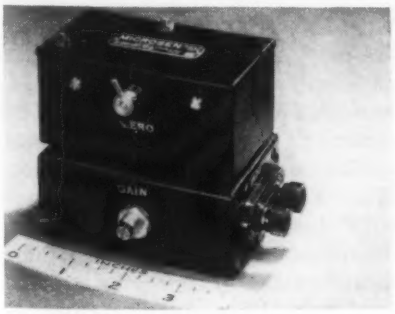


FIG. 4—Four inches long, this bench model of the d-c amplifier contains a miniature tube inside the chassis for applications where space is limited

The argument might be raised that this amplifier would only be useful in the laboratory, since a galvanometer is too fragile an instrument and is subject to accelerations and vibration. However, this application lends itself to a revamping of galvanometer design to give a very rugged structure.

Figure 3 shows a sketch of such a galvanometer. Since only a few thousandths motion is required of the flag moving between the oscillator coils, this design becomes feasible. Some advantages are immediately obvious. With the moving coil suspended in this manner, all coil turns are at right angles to the radial field and, therefore, useful.

In conventional galvanometer design, the portions of every turn that lie parallel to the magnetic field are wasted. So, too, a cylindrical coil is easier to wind than a conventional galvanometer coil, and the structure lends itself to the addition of the extra feedback coil without difficulty.

As a result of the small motion required, short frictionless leaf spring bearings may be used, making a more easily assembled movement. Having the coil at the end of the beam provides a torque-input current ratio that is higher than that usually attainable, but which would be detrimental were it not for the feedback used. The long natural period of the beam is reduced by feedback as has been shown.

Thus, combining the advantages of a high torque to current input ratio, rugged shockworthy construction, simplicity of assembly, and a fast time response as a result of feedback, the galvanometer is suitable for use as the input stage of a high-gain, stable field model d-c amplifier.

Practical Instrument

To answer a demand for an amplifier for aircraft purposes, the Microsen d-c amplifier pictured in Fig. 4 was developed. The unit shown is a bench model, flight models being shock-mounted and weather-sealed.

This instrument is exemplary of the general principles discussed, and its specific characteristics will

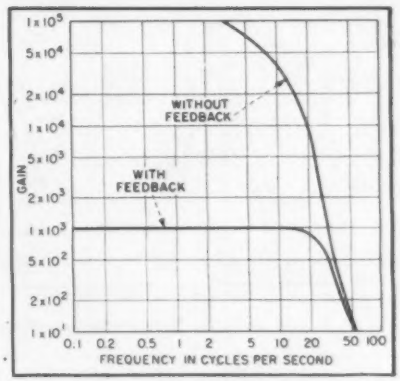


FIG. 5—Frequency characteristics of the electromechanical system with and without feedback

be considered in more detail. The design throughout was influenced by the stringent specifications of aircraft apparatus. It occupies less than 40 cubic inches, weighs approximately 2 pounds, requires less than 5 watts power and is mechanically constructed to insure its ability to withstand heavy vibrational and acceleration loading.

The circuit of Fig. 2A was used in this instance, and the feedback fraction chosen was 0.001, giving a gain of 1,000. Its specific use is to provide a voltage output of 5 volts for a thermocouple input of 5 millivolts. It is powered by an unregulated d-c supply of nominal 200-volt value. With line voltage variation from 100 to 200 volts, output drifts only 0.5 percent.

Feedback has greatly improved the time response as is witnessed by the frequency characteristics with and without feedback shown in Fig. 5. The gain remains constant as long as $\mu\beta$ is much greater than unity. At higher frequencies $\mu\beta$ becomes smaller as μ is reduced.

If it were desirable to extend the frequency characteristic and still retain the same gain, a stage of d-c amplification might be added, thus increasing $\mu\beta$ without increasing β, the reciprocal of the latter still determining the gain value. Of course, the gain is not limited to 1,000. Stable gains as high as 50,000 can be provided if the application demands.

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(1) Hendrik W. Bode, Network Analysis and Feedback Amplifier Design, D. Van Nostrand Co. 1945.

(2) Lawson: Analysis of D. C. Galvanometer Amplifier, *Electronic Engineering*, p 114-116, 17, Aug. 1944.

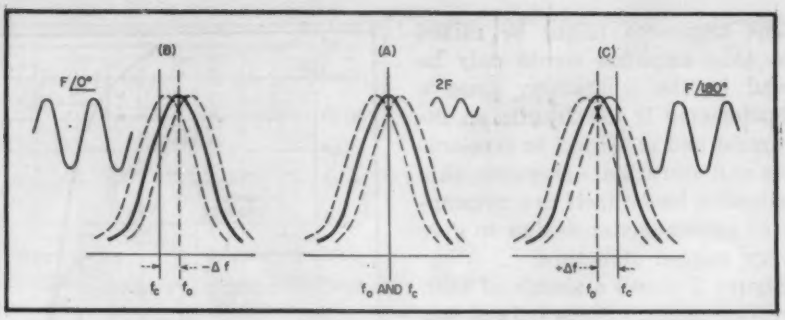


FIG. 1—Phase method of obtaining frequency drift sense

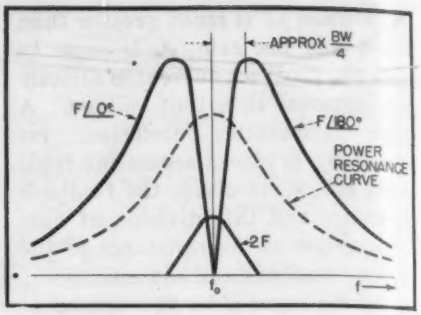


FIG. 2—Resonator-detector output

Simplified Microwave AFC

Part I

WITH the rapidly spreading interest in microwave relay systems, there appears a need for a relatively simple means of keeping a microwave oscillator within the required frequency tolerances. Accurately controlled temperature and voltages at the tube can be used with good success, but this requires complicated and bulky equipment.

Techniques using automatic frequency control (afc) of the microwave oscillator have also been developed, and many of these operate exceptionally well. Some of them have sufficient bandwidth and stability characteristics to provide a frequency correction to the oscillator of better than several parts per million over reasonable periods of time.

The afc system to be described is not as precise as the best that can be built, neither is it as complicated as a precision unit. Instead it is relatively simple, compact, easy to adjust, and can operate with either tunable klystrons or tunable magnetrons.

Most of the relay systems on microwave channels are rather wide band, in the order of 2 mc or more. Consequently, if the transmitter carrier is held to within about ± 200 kc of the assigned frequency, it will remain well within the channel limits. A simplified motor-operated afc system will serve.

In all automatic frequency control systems, the frequency of the controlled oscillator is compared with a known reference frequency, and any discrepancy between the two, as indicated by the detection circuit, is used to apply a correction to the afc oscillator. One method uses a cavity resonator as the reference frequency standard. The resonator is used in such a way as to obtain a sensing or directioning of the oscillator drifts for applying the proper corrections. This correction may be accomplished by coupling the resonator to a waveguide bridge circuit.[1]

The type of sensing used in the system to be described is somewhat novel because it applies a sensing modulation to the reference resonator itself. This sensing modulation provides a means of detecting the magnitude and direction of frequency shift of the oscillator. The signal carrying this information is used to shift the oscillator back to the correct frequency setting. Either mechanical or electronic means can be used to tune the tube, or both can be used in combination.

Several useful afc systems are discussed: motor afc system alone; motor and reflector afc system combination; pushbutton scanning means for such systems; automatic scanning means. Their discussion is preceded by an analysis of certain basic operating principles.

Method of Sensing

If the resonant frequency of an excited resonator is moved back and forth at a given rate, the resulting signal from a crystal detector coupled to the cavity is in phase with the signal producing the resonant frequency shift when the carrier is effectively detuned to one side of resonance, and 180 degrees out of phase when it is detuned to the other side of resonance. As far as the crystal detector is concerned, variation of the cavity resonant frequency is equivalent to frequency modulation of the carrier generator. When the carrier is exactly in tune with the resonator, the detector output is entirely the second harmonic of the sweep rate, with no fundamental component present.

Figures 1 and 2 illustrate these basic sensing functions graphically. Figure 2 shows that increasing the

* The equipment described was developed while the author was with Sperry Gyroscope Co.

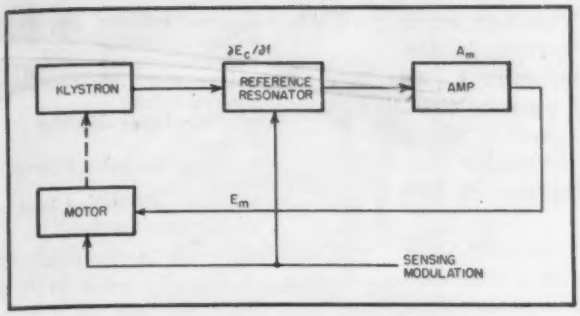


FIG. 3—A basic motor-operated automatic frequency control

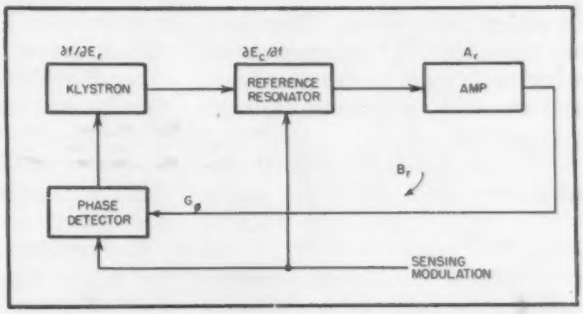


FIG. 4—A basic electronic automatic frequency control

Combinations of motor and electronic afc action for microwave oscillators are discussed. Methods of automatic and manual correction scanning complete the design considerations for a 3,000-mc radio-relay system that remains within 200 kc of assigned frequency

By F. A. JENKS *Raytheon Manufacturing Co. Waltham, Mass.**

carrier detuning will enhance the voltage of the fundamental frequency-modulating frequency obtained from the crystal detector until the detuning has gone about one-quarter of the resonator bandwidth, at which point the voltage of the fundamental begins to drop off, although remaining in the same phase. The output signal from the detector crystal is a reversing-phase variable-magnitude voltage of the same frequency as that used to modulate the resonator.

Figure 2 is correct for small frequency deviations of the resonator frequency, a condition which is employed in the present afc system. Wider deviations move the fundamental peaks out to about the half-power points on the resonance curve. The slope of the fundamental curve at or near resonance is called the conversion factor or sensitivity of the resonator-detector unit, dE_c/df, and is stated in volts per cycle for a given radio-frequency power into the resonator and a given frequency deviation.

To prevent modulation of the cavity from reacting on the oscillator, careful adjustment of the coupling between the two is necessary. It is desirable to use only a small amount of power in the resonator, as this aids in meeting the decoupling requirement by allowing loose coupling and avoids absorbing too much energy from the oscillator.

Basic Motor AFC

To illustrate each functional section of the complete afc system, the two methods of control will be discussed separately. Figure 3 shows a block diagram of the essential elements of the motor afc without antihunt. Since the resonator-detector output is a reversing-phase variable-magnitude voltage of the fundamental sweep frequency, it is suitable for operating a two-phase motor. If one winding is excited with a constant voltage of fixed phase, and the other, called the control winding, is excited by a variable-magnitude voltage of either 0 or 180-deg phase relationship with respect to the first winding, the direction of rotation of the motor will depend upon whether 0-deg or 180-deg phase voltage is in the control winding. The speed at which the motor runs is dependent upon the amplitude of the voltage in the control winding, with zero voltage producing no rotation, even though full voltage is maintained on the first or reference phase winding. The motor, in essence, becomes a phase detector in this type of afc system.

From the diagram of Fig. 3, it is seen that the resonator-detector signal is amplified and applied directly to the control winding of the motor. The fixed phase winding derives its excitation from the same source that is used to produce the resonator frequency deviations for the sensing operations.

Since the two-phase motor is a mechanical device, it is subject to certain evils, namely bearing friction, inertia, and unbalance. In a good motor the rotor will be balanced rather carefully, and static inertia troubles will not begin to appear until the static friction in the bearings has been virtually eliminated. Owing to this friction, a finite signal voltage E_m at the motor winding is needed to overcome these forces and produce rotation. Usually the rotational friction is lower than the static friction, and consequently it is not the important factor in the problem.

Assuming then that the system is exactly in tune, no fundamental voltage will appear at the motor winding. As the oscillator begins to drift, the error signal on the motor winding has to reach a value of E_m volts before motor-operated

afc action takes place. Therefore, the unavoidable frequency error owing to friction is the frequency drift required to produce E_m volts at the motor.

Referring again to Fig. 3, the terms used to describe the action around the feedback loop may be summarized and defined. E_m is the motor voltage required to overcome static friction; dE_c/df is the resonator-detector voltage frequency sensitivity, near resonance; A_m is the gain of the motor amplifier section; Δf is the frequency deviation error without afc.

To cause afc action to take place the error signal must equal E_m, and that quantity may be evaluated by

$$E_m = A_m\,(dE_c/df)\,\Delta f \qquad (1)$$

Solving for the frequency error produced by the motor afc because of frictional forces gives

$$\Delta f_m = (E_m/A_m)\,(df/dE_c) \qquad (2)$$

The error shown in Eq. 2 is the long-time error encountered in the motor-operated type of afc system (assuming negligible resonator and modulator drift), since the motor will drive until the error voltage on its winding has reached some value less than E_m. Driving toward the correct frequency, the inertia of the mechanical system will carry the tuning well into the region where the error signal is less than E_m. The fact that rotational frictional at slow speeds is less than static friction emphasizes this condition.

It may happen that the mechanical inertia of the gear train actually carries the tuning through the correct value and to a reverse voltage greater than E_m. This new error signal drives the system in the other direction and the overrun may then be encountered a second time. This can result in hunting, where the motor oscillates the tuning back and forth around the correct frequency setting.

The problem of eliminating hunting will be taken up in a later section. The correction response time of the motor afc is usually slow due to the mass and drag of the mechanical linkages.

Basic Electronic AFC

Using electronic afc, for example by varying the reflector voltage of a reflex klystron, a residual error signal is required to produce a correction voltage with which the afc must operate. This is unlike the motor-operated afc in which the error signal would go to zero if no static frictional forces existed. Figure 4 shows a block diagram of an electronic afc section. The essential difference between this and the previous case is the replacement of the motor by a phase-detector whose output is coupled directly into the reflector circuit of a klystron. Since the reflector is frequency-voltage sensitive, the control loop is complete to provide afc action.

As such an electronic afc system does not have any mechanical circuits, it can be treated in the usual feedback manner. The terms used around the feedback loop in Fig. 4 are defined as follows:

G_ϕ = conversion gain of phase detector

df/dE_r = klystron reflector frequency–voltage sensitivity

dE_c/df = resonator-detector voltage-frequency sensitivity near resonance (as before)

A_r = gain of reflector amplifier section

Δf = frequency deviation error without afc

B_r = feedback gain around loop, excluding amplifier A_r

The residual error in the electronic afc is the frequency error drift divided by the total loop gain

$$\Delta f_r = \frac{\Delta f}{\text{loop gain}} = \frac{\Delta f}{A_r B_r} \qquad (3)$$

$$A_r B_r = A_r \left(G_\phi \frac{df}{dE_r} \frac{dE_c}{df} \right) \qquad (4)$$

Substituting Eq. 4 in Eq. 3

$$\Delta f_r = \frac{\Delta f}{A_r\, G_\phi \dfrac{df}{dE_r} \dfrac{dE_c}{df}} \qquad (5)$$

The residual error signal can be made smaller by increasing the gain around the feedback loop ($A_r B_r$).

Combination Motor and Electronic AFC

The motor and electronic afc systems have one interesting thing in common; neither afc system can produce complete error correction. The motor system is afflicted with frictional troubles, and the electronic system requires some error signal to produce afc action. Operating in combination, however, the electronic afc has to handle all transient errors greater than the maximum frequency error allowed by the motor friction given by Eq. 2. Its long-time error signal will be less than this amount. Consequently, the resulting long-time error of the combined systems is given by substituting Eq. 2 into Eq. 5

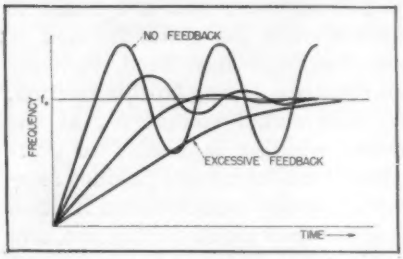


FIG. 5—Motor tuning time plotted against corrective feedback

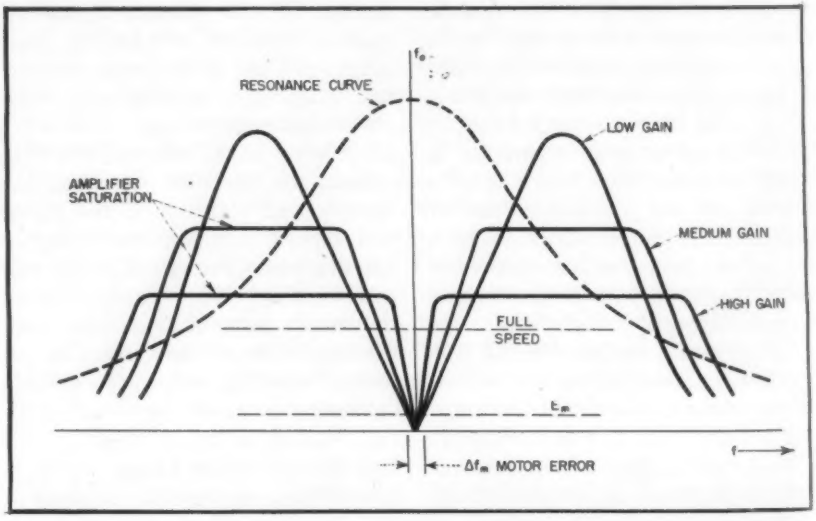
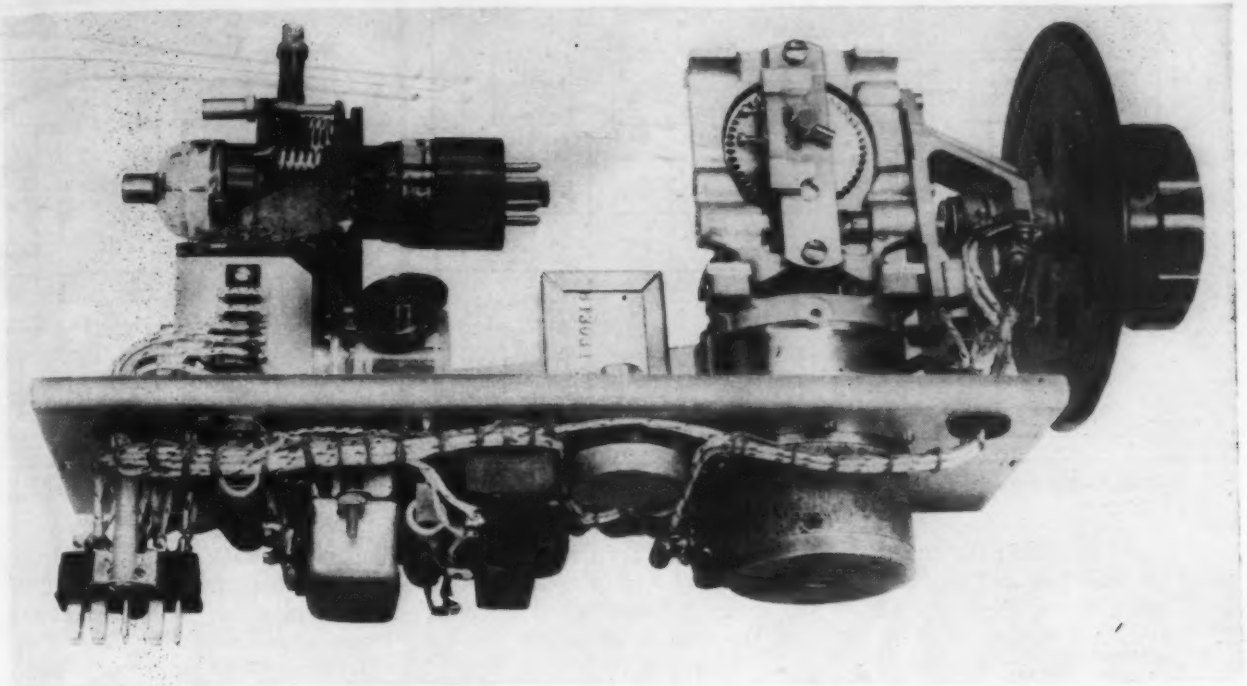


FIG. 6—The hold-in characteristic versus motor-amplifier gain indicates how well motor error can be compensated



Microwave section of signal generator. Resonator and speaker-unit modulator are shown beneath the gear mechanism at right. Tuning motor with cam is above chassis at left

$$\Delta f_{mr} = \frac{\Delta f_m}{A_r B_r} = \frac{(df/dE_c)\ (E_m/A_m)}{(df/dE_r)\ (dE_c/df)} \quad (6)$$

$$\Delta f_{mr} = \left(\frac{df}{dE_c}\right)^2 \left(\frac{dE_r}{df}\right) \left(\frac{E_m}{A_m\ A_r\ G_\phi}\right) \quad (7)$$

Several things are gained when the electronic afc system is combined with the motor-operated afc. First, the response of the electronic system is faster than its mechanical counterpart. This feature relieves the motor of trying to respond to transients which it can not handle. Second, the quicker action of the electronic system acts as an antihunt circuit for the motor afc. If the motor inertia carries the corrective tuning past the center frequency, the electronic afc corrects this situation by electronic tuning, thus wiping out or materially reducing (by an amount equal to $-\Delta f/A_r B_r$) the reverse error signal which the motor winding would have otherwise seen. Action such as this removes any tendency to hunt or oscillate about the center frequency, and gives a smoothly damped motor operation. Third, when the combined system is in tune, the output from the phase detector is zero.

This last condition is most important in transmitters whose modulation characteristics are critical as to distortion, and the oscillator must be operated at the center of a mode as dictated by the reflector characteristics. Consider a step-function frequency disturbance. The action of the electronic afc causes it to make its best possible correction as given by Eq. 5. During this time the motor has also begun to operate, to wipe out the error voltage on its winding. As the system approaches the correct mechanical tuning of the klystron, the error voltage is reduced. When the correction is complete, the output of the phase detector goes essentially to zero, thereby putting no additional voltage from electronic afc action onto the already existing reflector potential. In this way, the best modulation characteristics are maintained, even under rather severe afc hold-in conditions.

Motor Circuit Antihunt Control

When the motor-operated afc is considered alone, some means of reducing the tendency to oscillate about the center-frequency must be introduced. One of the most satisfactory methods is to couple an eddy current generator to the motor shaft, and excite one of its fields at the motor frequency. The amplitude of the resulting voltage in its output winding will be proportional to the speed of the motor, and its phase will be either 0 or 180 deg with respect to the exciting voltage, depending upon the direction of rotation. No slip rings are needed so no additional friction forces are incurred.

The eddy-current generator signal is introduced into the motor control circuit in such a way that its phase is in opposition to that of the error signal. When a frequency disturbance occurs, the motor operates to reduce the error as usual, but some signal of opposite phase proportional to the motor speed is supplied by the generator to reduce the apparent error signal. Such a reduction in error voltage slows down the motor, which procedure in turn reduces the injected antihunt voltage.

Should the inertia of the mechanical system carry the correction too far, and cross the center frequency, the error signal will change phase. This condition puts both error and antihunt signals in phase, and the sum of the two act to brake and reverse the direction of rotation. Once this reversal is accomplished they are again out of phase, because the phase of the generator voltage depends upon the direction of shaft rotation only, and the antihunt signal is again tending to slow down the motor. One important

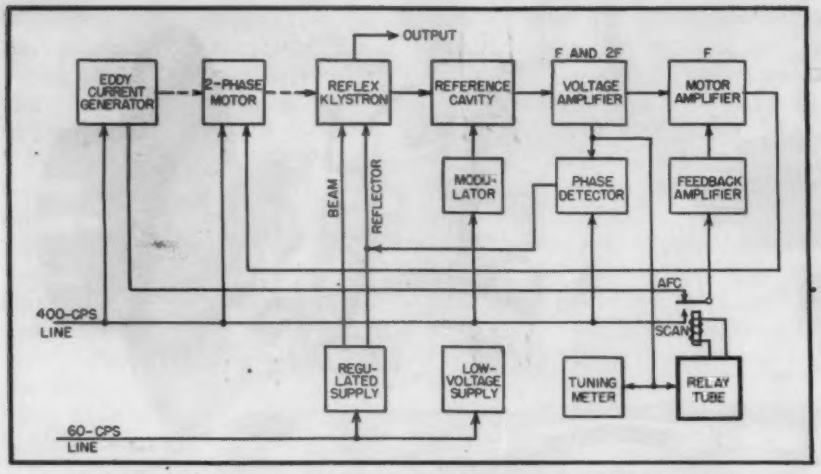


FIG. 7—Block diagram of a motor afc system connected for antihunting

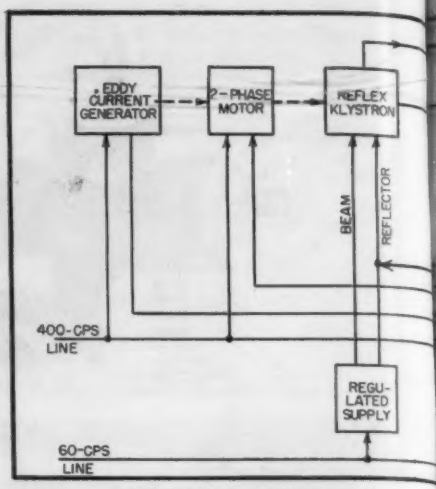


FIG. 8—Block diagram of

point should be noted; the antihunt signal becomes less and less as the motor slows down when approaching the correct tuning, and it is zero when the motor arrives at a dead stop. In this latter condition the system has its greatest sensitivity.

The amplitude of the antihunt signal plays a large part in determining the characteristics of the motor afc system. In Fig. 5 is shown a series of curves for different amounts of speed feedback voltage. It is possible to go from the case of oscillation with no antihunt voltage through a gradual approach to the condition with no overshoot, and beyond to a point using excessive antihunt signal. The proper adjustment is somewhere between the two extremes, depending upon the operating requirements of the individual equipment.

Hold-in Tightness

From Eq. 2 it is apparent that the motor error caused by static friction varies inversely as the gain of the motor amplifier, A_m. Figure 6 illustrates a family of curves which show increasing tightness of afc control (that is, less frequency error) with increasing amplifier gain. The section near the center, before overloading occurs, is most interesting. As the gain increases, the motor-error width decreases accordingly.

The ability of the system to respond to transient disturbances is dependent upon the electronic afc. Assuming that a 400-cps motor is used, and the same sensing frequency is used for both motor and electronic afc, it is apparent that the error information is arriving into the system at only a 400-cps rate. This relatively slow rate of gathering information puts a definite limit upon the transient response of the electronic afc. If at least 20 complete information cycles are needed for reproducing error data of a transient pulse, then the transient response that can be handled by such a system is in the order of 0.1 second, or longer.

The difficulty in filtering out 400 cps from the output of the phase detector to prevent 400-cps frequency modulation of the klystron necessitated a brute-force filter, which would preclude attempting to raise the transient response when using such a low sensing frequency. It is entirely possible to use two sensing frequencies to overcome this trouble, such as 400 cps for motor control and 50 kc to 100 kc for electronic control, with good transient response.

Motor AFC with Antihunt Generator

The simplest form of afc system that has been discussed is one using just motor control, with antihunt signals supplied by an eddy-current generator. A block diagram of this arrangement is shown in Fig. 7. The performance to be expected from this circuit is given by Eq. 2, and the response to transients is relatively poor. However, such an afc is characterized by extreme simplicity, low power drain, compact size, and a wide tuning range.

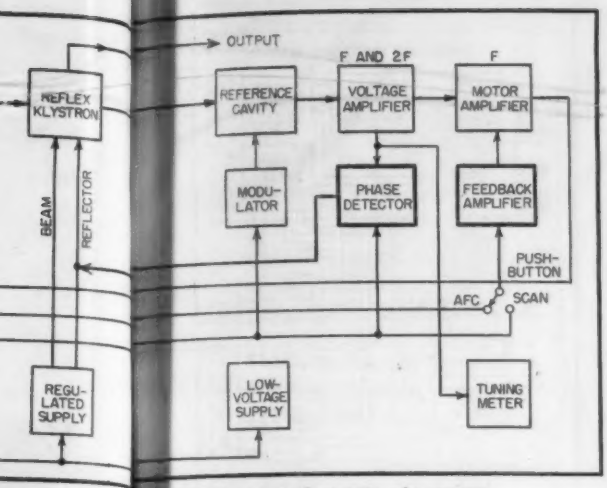
The mechanical details are most important, such as good linkages between the motor shaft and the tuning member, stable frequency-temperature characteristics of the reference resonator, and stable resonator-modulator characteristics. Some means of reducing the second harmonic voltage of the sensing frequency is necessary to prevent overheating the motor winding with a signal that contributes no rotational torque.

A slightly different type of motor-operated afc is possible by coupling the motor to a potentiometer which in turn varies the reflector voltage of the reflex klystron. No mechanical work is done on the klystron, consequently less torque is needed from the motor. The frequency control range of this system is limited, however, to the electrical tuning of the reflector circuit. Unlike the electronic afc, no sensing voltage has to be filtered from the reflector circuit.

Motor-Electronic System

The combination of motor and electronic afc systems gives more flexibility of operation. Figure 8 shows a block diagram of this combination system. Note that the antihunt signals for the motor are now amplified in a separate stage and fed into the signal amplifier at a point beyond where the phase detector signals are picked off. The change in antihunt injection is necessary to prevent the generator voltage from getting into the phase detector circuit.

Several points of caution are necessary to observe if this com-



motor and electronic afc system

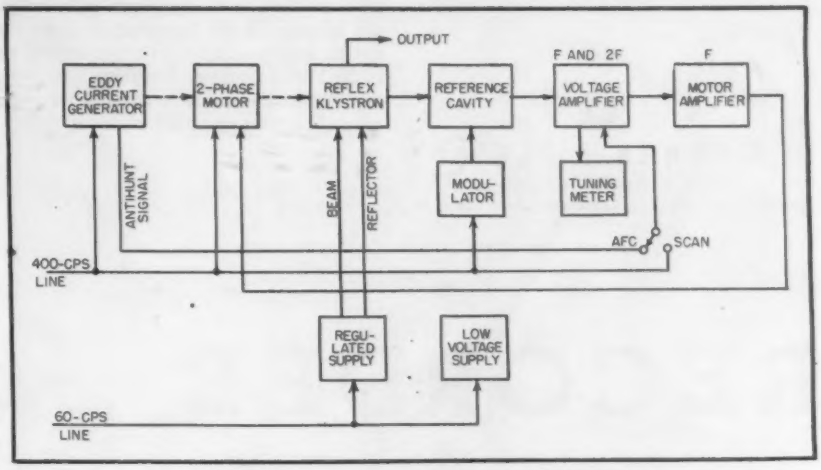


FIG. 9—Block diagram of an afc system with automatic scan

bination afc is to function properly. Referring again to Fig. 8, the phase of the signal at the motor winding should be either 0 or 180 deg with respect to the voltage on its fixed phase winding. The phase of the amplified antihunt signal should be 180 deg with respect to the signal voltage at the point of injection into the motor amplifier chain. Last, the phase of the signal voltage at the secondary winding of the pushpull transformer of the phase detector should be either 0 or 180 deg with respect to the reference voltage in the center leg of the phase detector. Also, the frequency response around the electronic afc loop should drop to unity before the phase shift has reached 180 deg, otherwise the reflector afc will oscillate at the frequency where the 180-deg shift occurs.

Pushbutton Scanning

The two systems described above will pull into frequency if the drifting oscillator signal is within the skirts of the reference resonator response. However, the oscillator may not be within this frequency range, especially with a tunable reference resonator as used in signal generator applications. To make the motor tune the oscillator without error signal from the resonator, a switch or pushbutton arrangement can be used to inject scanning voltage into the motor amplifier and to disconnect the motor antihunt signals during the scanning operation.

The simplest method is to allow the motor to drive always in the same direction during scanning. If the resonator is tunable or channelled, a better method is to connect a set of contacts to the frequency-shifting mechanism which selects the proper phase of the scanning voltage for driving in the correct direction. Such a scheme will be described in more detail in a later section.

Automatic Scanning

Certain applications require that the afc system automatically search and lock onto the signal if it should not be within the pass-band limits of the reference resonator. This type of operation is relatively easy to accomplish with the afc equipment under discussion.

Figure 2 shows the output voltages from the resonator-detector within the resonant characteristics of the cavity. Notice that the second harmonic of the sensing modulation frequency peaks at resonance, while the fundamental goes to zero. It is obvious then that if both the fundamental and second harmonic frequencies are amplified and rectified, a control bias can be developed whenever the carrier lies within the resonator limits. Should the carrier drop out of the pass band of the resonator, no bias will be produced and scanning can be made to commence. An automatic scanning system is shown in block diagram form in Fig. 9.

First, it is important that the d-c bias developed by this rectified sensing signal be sufficiently great at resonance to cut off the control or relay tube with a reasonable margin of safety. Second, if this bias is used to cut off a scanning tube (instead of operate a relay tube) it must be great enough to eliminate completely all trace of scanning voltage in its output circuit; otherwise the afc system will remain slightly off to one side or the other of resonance. During scanning, some means to reduce or eliminate the speed feedback voltage is required. If this reduction is not effected the scanning will be slow and jerky.

A more desirable method than cutting off a vacuum tube is to use the bias voltage to operate a relay tube. The relay, when relaxed, allows the generator feedback voltage to be applied in the normal manner, and when energized it injects scanning voltage into the system instead of antihunt voltage from the generator.

As mentioned earlier, the phase of the scanning voltage can be selected automatically so that the motor will drive in the shortest direction to pick up the signal. A pair of contacts operated by the resonator tuning or channeling mechanism though a clutch will work satisfactorily for this phasing operation.

The special components used in a representative system and their necessary physical properties will be described in the second and concluding part of this article, to appear in a forthcoming issue.

Reference

(1) R. V. Pound, Electronic Frequency Stabilization of Microwave Oscillators, Rev. Sci. Instr., p 490, Nov. 1946.

By
WARREN H. BLISS
RCA Laboratories Division,
Radio Corporation of America, Princeton, N. J.

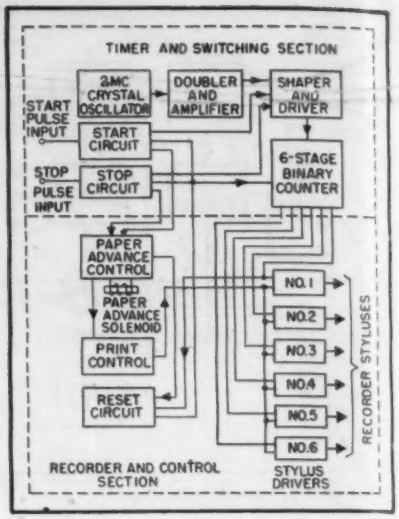


FIG. 1—Start and stop input pulses limit the duration of the high-frequency train of cycles delivered by the shaper and driver to the binary counter. Count attained when the stop pulse occurs is marked on paper by the recorder styluses

RECORDER and TIMER for Short Intervals

Designed to meet the needs of nucleonic research, this interval timer measures and records intervals up to 16 microseconds with an accuracy of 0.25 microsecond. Intervals to be measured may occur at random and be widely separated

NUMEROUS RESEARCH projects, and the field of nucleonics in particular, require a practical method of measuring very short time intervals that occur at random. Lengths of periodic or recurring intervals can be observed by conventional oscilloscope patterns, but when it is desired to measure the interval between a pair of closely spaced pulses that may appear only a few times in an hour, the technique is difficult. A common method of measurement has been to use a long-persistence cathode-ray trace with rotary sweep and triggered control. For measurements of the order of a few microseconds, the sweep speed must be so great that the trace is dim and hard to photograph or observe.

Gated Counter Technique

A better method has been found by the application of electronic counter techniques. Currently available commercial counters do not have as good resolution as desired for such measurements, and do not record the result and repeat the operation automatically. Consequently, a special development was undertaken that resulted in the design and construction of the Short Interval Timer and Recorder (sometimes called SITAR).

System Operation

The basic element of the interval timer is a binary scaler or counter chain connected through a gating circuit to a 4-mc driving source. Pulses marking off the interval to be measured are applied to a gate or switching circuit which passes a representative block of the high-frequency cycles to the binary chain, where they are counted and registered. The result is then automatically recorded as a dot pattern across a strip of special paper and the machine resets itself in readiness for the next measurement.

The block diagram of Fig. 1 illustrates the various elements of the device with the necessary interconnections. The components are arranged physically in two groups and are mounted accordingly on two chassis units. The upper section contains the 4-mc source, the switching circuit, and the counter chain. The lower section contains the recorder, its control circuits, and the reset circuit which restores the upper section to its standby condition after each measurement.

The 4-mc timing frequency is obtained by doubling the output of a 2-mc crystal oscillator. A shaper and driver stage, under control of start and stop elements, transmit a gated block of 4-mc pulses to the counter. The initiating and terminating pulses of the time interval to be measured are applied to trigger the start and stop circuits, respectively.

The counter or scaling circuit consists of six binary stages of the usual locking-trigger type and has a capacity of 64 counts (2^6). Because the head or highest-speed

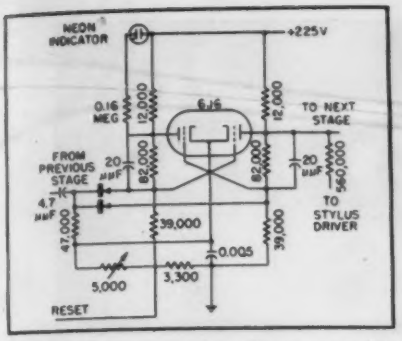


FIG. 2—Binary counter stages use this typical flip-flop circuit

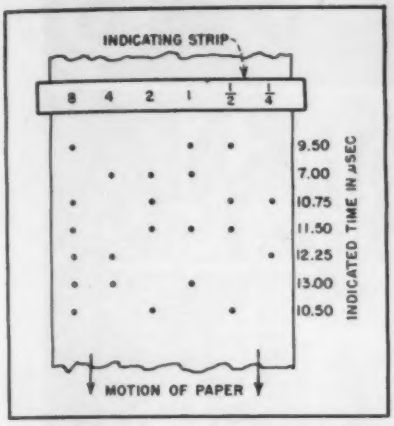
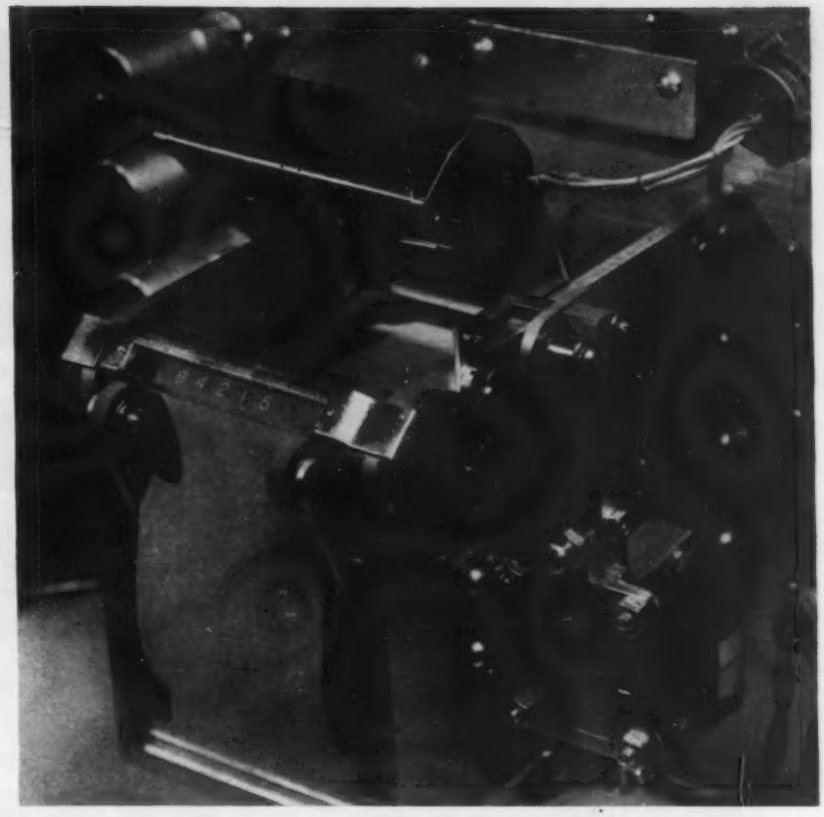


FIG. 3—Interval measurements are shown as rows of dots. Sum of dot values in each row equals interval duration



Six styluses projecting from the raised recorder head electrically mark the count on a 2.25-inch strip of Teledeltos paper. Strip is advanced in one-eighth inch steps by the ratchet wheel and magnet-actuated pawl on right of housing

stage operates at a 4-mc rate, the time capacity of the chain is 16 microseconds and the definition is ±0.25 microsecond. Obviously the capacity could be increased by adding more stages. At the end of any given count, the result is shown by the positions in which the various stages are left after receiving the last input pulse. This information is indicated directly by means of neon lamps and is transmitted to the recorder. A typical binary stage as used in the SITAR is shown in Fig. 2.

Interval Recording

In the recorder and control section the paper advance control is triggered at the end of the count or measurement and the recording paper is moved ahead one space. While the paper is in motion the print control circuit produces a trigger pulse to trip the stylus drivers. The gas-tube stylus drivers respond according to received information from the counter and apply current through the appropriate styluses to print the result as a row of dots on the recording paper.

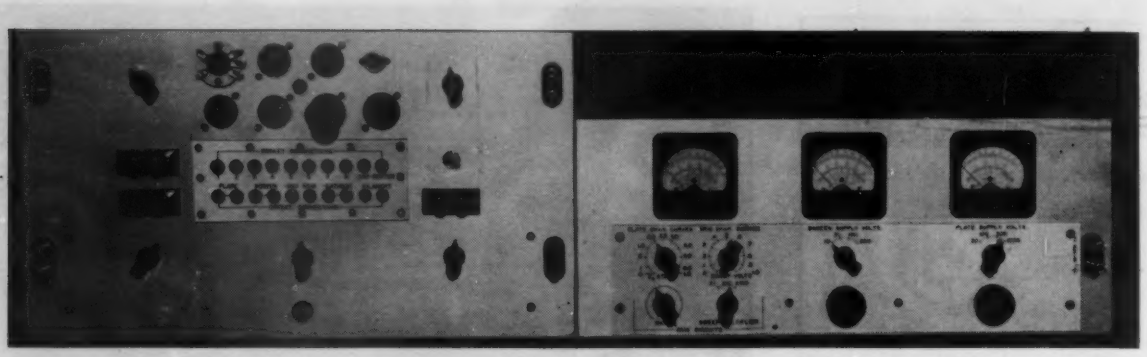
After each recorder operation, the reset circuit is tripped. This circuit supplies suitable reset pulses to the start and stop tubes and the counter chain to restore them to the zero or standby condition. If an applied start pulse is not followed within 16 microseconds by a stop pulse, the equipment automatically resets itself. An interlock connection allows the stop circuit to be tripped only after the start circuit has operated. Thus the interval timer is protected against false operation due to any stray or unwanted pulses that may be applied to it.

Figure 3 illustrates the nature of the record and how it is read.

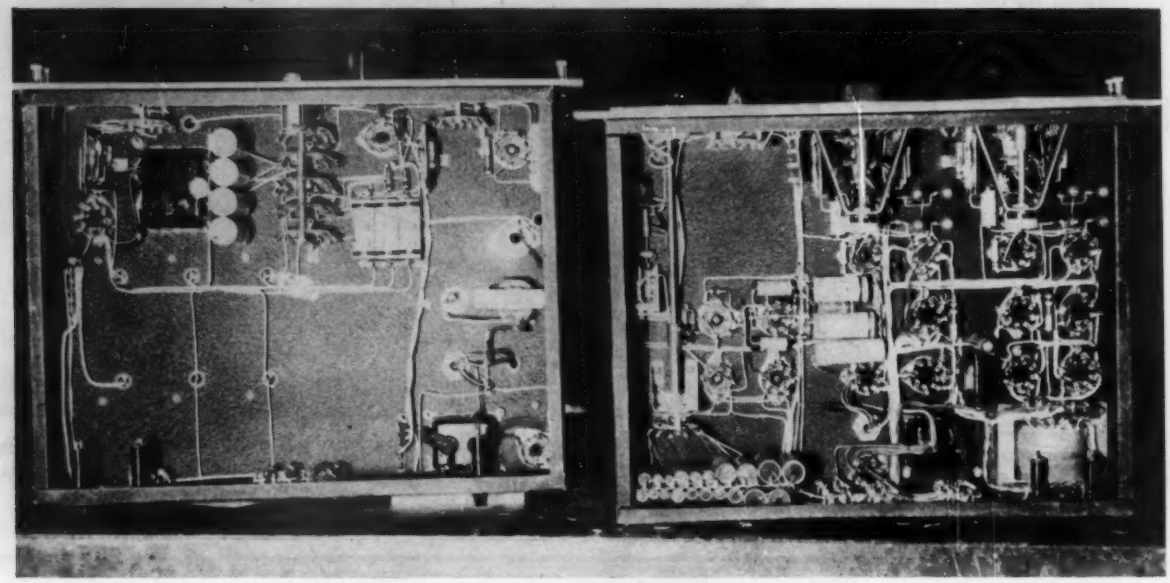
Timing Precision

The interval timer and recorder has possible application in many fields. The device offers a practical means of making time interval measurements in which the interval is very short and does not repeat. Each pair of applied start-stop pulses causes an independent measurement to be made and recorded. Due to the mechanical action of moving the record paper, each measurement requires approximately 0.5 second to complete. The time between measurements may be as long as desired because the circuit will remain in the standby condition indefinitely.

The timer was designed and built to meet a request from the Physics Department of Princeton University. The machine is being successfully used there in current nuclear research. It was originally equipped to have a definition of ±0.5 microsecond but this was improved later to ±0.25 microsecond. Use of techniques and circuits more recently developed would make it entirely possible to construct a machine having a timing frequency as high as 10 mc, giving a definition of ±0.1 microsecond.



Front panels of equipment contain sockets for all types of tubes



Wiring is kept close to chassis to minimize stray fields

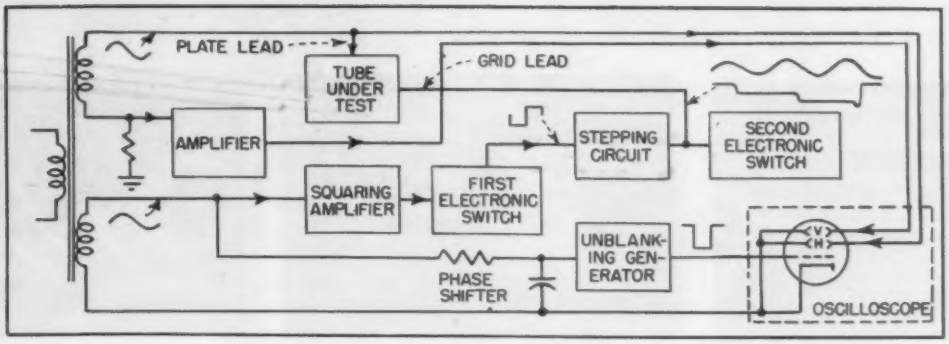
Producing Tube Curves

AN EASY and common method of predicting performance of vacuum tubes is by using plate-current versus plate-voltage characteristic curves, commonly called plate characteristic curves, and plate-current versus grid-voltage or transfer characteristic curves. From these curves it is possible to determine, among other things, plate resistance of the tube, amplification factor, transconductance, power output, and percentage of harmonic distortion introduced.

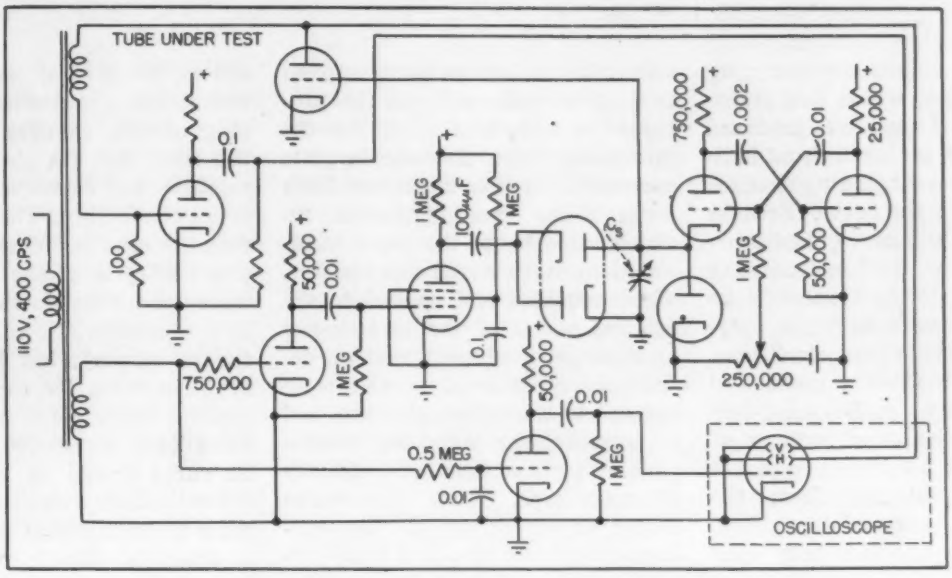
Desirability of More Curves

Useful as they may be, ordinarily available curves are subject to limitations. For instance, plate characteristic curves such as are given in tube manuals and electronic books are usually static curves and, for pentodes, are given only for one particular set of screen and suppressor grid voltages. From the designer's standpoint, a set of characteristic curves for each possible combination of these voltages would be very advantageous. With such a set of curves, it would be easy to select the optimum set of conditions under which to operate the particular tube. In the design of audio amplifiers, for example, it would be a relatively simple problem to select the set of operating conditions under which a given output could be obtained with minimum distortion. In electronic control systems, where the irregular portions of the characteristic curves are utilized, a complete set of these curves would enable the designer to pick the operating conditions under which these irregularities could be used to greatest advantage.

Desirable as it would be, to include in tube manuals such a set of curves is impractical, because of the vast number that would be required. The designer then has two choices. He may be satisfied with one set of static curves from which to make his calculations or he may actually plot, point by point, a set of curves for each given set of conditions. Such a process is long and laborious and unless an excessive number of readings are taken, small irregularities, such as appear on 6L6



Block diagram relates elements of system



Circuit shows principal components of each stage

on an Oscilloscope

Stepping circuit switches grid voltage after each characteristic curve is traced on cathode-ray oscilloscope. In this way a complete family of curves is automatically produced. Equipment makes possible rapid and detailed studies of all factors affecting tube operation

By HENRY E. WEBKING

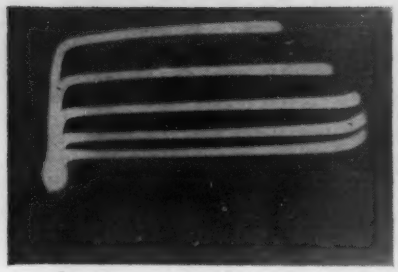
Graduate Assistant
Department of Electrical Engineering
Oklahoma Agricultural and Mechanical College
Stillwater, Okla.

characteristic curves, are not likely to show.

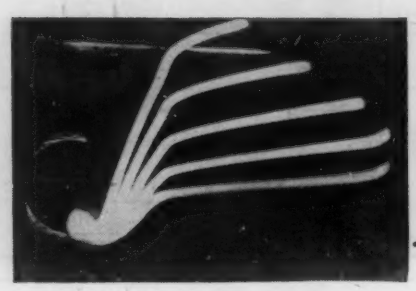
Automatic Curve Plotter

Instead of manually plotting such curves, the circuit given here offers a method of showing these characteristic curves on the screen of a cathode-ray tube.[1] By the use of a few calibrated controls, it is possible to produce practically any combination of operating conditions and to observe the shape of the curves under these conditions, as demonstrated by the accompanying traces obtained with this equipment. These curves offer a visual indication of the changes in such things as amplification and linearity with changes in operating conditions. Additional flexibility is provided by controls on the front panel which vary the magnitude of the grid bias steps as well as the number of steps. Consequently, any number of curves with any desired spacing may be shown on the screen of the cathode-ray tube.

In addition to the plate characteristic curves, this circuit (by changing connections to the tube under test) is capable of producing a dynamic transfer characteristic curve (grid-voltage versus plate-current curve) on the screen of the cathode-ray tube. As with the plate



Family of plate curves for 6SK7



Type 6SK7 connected as tetrode

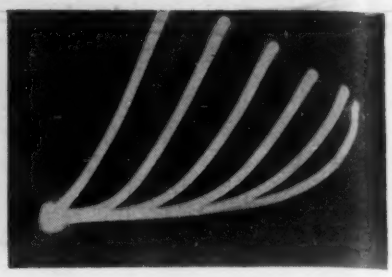


Plate characteristics of 6J5

characteristic curves, the operating conditions under which this transfer characteristic curve is produced may be varied, giving a visual indication of the corresponding changes in the shape of the curve. Because this is a dynamic curve, nonlinearity of the curve itself indicates the amount of distortion that will be produced by the tube when operated under the given conditions. This fact is utilized a great deal in the design of audio amplifiers even though the usual manner of obtaining such a curve is to plot it with values obtained from the tube's plate characteristic curves. The technique has also been used to measure tube characteristics under extreme conditions.[3]

The equipment is so constructed that any type of tube can be tested. Meters are built in to indicate the various element voltages. A switch located in the middle of the larger panel has five positions and enables the operator to show curves of (1) plate current versus plate voltage, (2) screen current versus plate voltage, (3) plate current versus control grid voltage, (4) screen current versus control grid voltage, and (5) output waveform of the tube with an external signal applied to the grid.

Circuit Operation

The block diagram shows the complete circuit. A 110-volt 400-cps sinewave (readily available from surplus aircraft dynamotors) is fed into the primary of the transformer, producing sinewave voltages across both secondary windings. The high frequency is used to avoid flicker on the cathode-ray tube, which would be noticeable at 60 cps. The 300-volt rms voltage across the upper winding is applied to the tube under test and also provides the horizontal sweep for the cathode-ray tube. Because the plate current of the tube under test flows through the small grounded resistor connected to the upper winding, the voltage across this resistor, when amplified and applied to the vertical plates of the cathode-ray oscilloscope, produces a vertical deflection proportional to the plate current in the tube under test and in synchronism with the corresponding plate voltage independently of waveshape. Thus the curve traced on the screen of the oscilloscope will be a graph of plate current versus plate voltage or a plate characteristic curve.

The output voltage of the lower transformer secondary winding is first fed into a squaring (overdriven) amplifier. (Coming from the common source, this voltage is in synchronism with that applied to the tube under test.) This amplifier changes the sinewave input into a squarewave and changes the phase by 180 degrees. The resultant squarewave is fed into the first electronic switch, which in turn applies voltage on alternate half-cycles to the stepping circuit, the switch being closed during positive half-cycles of its squarewave input and open during negative half-cycles.

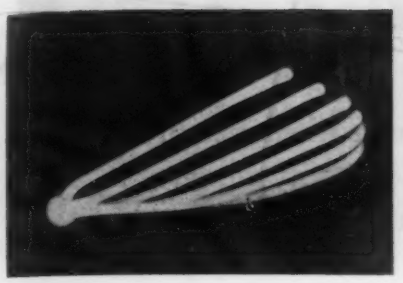
The stepping circuit is so arranged that each time voltage is applied, its output voltage will increase by a predetermined amount. Because the first electronic switch applies voltage to the stepping circuit only on alternate half-cycles, the output voltage will correspondingly increase only on alternate half-cycles. Consequently the voltage on the grid of the tube under test, which is controlled by the stepping circuit, changes only during the time that its plate voltage is negative and consequently when it is not conducting. The grid voltage remains constant during the positive half-cycle of the applied sinewave (the time during which the plate characteristic curve is traced on the screen), but has a larger negative value for each successive positive half-cycle of plate voltage. Thus each successive characteristic curve traced on the screen of the cathode-ray oscilloscope will be for a larger value of grid bias, and a complete family of curves is traced.

This process continues until the maximum desired value of grid bias is reached. At this time, the second electronic switch operates long enough to reduce the stepping circuit output voltage to zero. The stepping process is then repeated.

The output of the lower secondary is also fed into a 90-degree phase-shifter ($10X_c \leq R$) and its output in turn is applied to the unblanking pulse generator (squaring amplifier). Its squarewave output, applied to the control grid of the cathode-ray tube, is used to increase the beam intensity during the time that the plate voltage of the tube under test is increasing and thus during the first quarter-cycle of the applied sinewave, or for the time that each plate characteristic curve is being traced on the screen of the oscilloscope.

Stepping Circuit

The second electronic switch, which discharges the grid voltage stepping circuit, is designed so that it remains open until the voltage



Type 6J7 with cathode degeneration

Nonlinear portion of 6L6 curves

across it builds up to a predetermined value, at which time it closes and remains closed until the voltage across it decreases nearly to zero. As shown in the circuit diagram, in which all elements are in their same relative positions as in the block diagram, this second electronic switch can be a one-shot multivibrator with the lefthand tube normally beyond cutoff. The first electronic switch is a gated pentode, while the stepping circuit proper is a variable capacitor having one value of 0.01 microfarad.

During the positive half-cycle of the applied sinewave, the first electronic switch is open (pentode cut off) and the capacitor in its output is charged through one half of the duodiode to approximately the d-c power supply voltage. The R-C time constant of this circuit should be a small fraction (1/20) of the period of the base frequency to permit full charging in the half-cycle. During the negative half-cycle of the input sinewave (squared before being applied to the switch) this switch is closed and its output capacitor discharges through the other half of the duodiode, thereby charging the grid voltage stepping capacitor and making the grid of the tube under test become more negative with respect to ground. The voltage step produced across the stepping circuit depends on the ratio of its capacitor to that in the output of the first switch and the plate d-c supply voltage ($N \approx CE_{bb}/C_s$, where N is the voltage of each step). The second electronic switch is open during this operation.

The charging of the stepping circuit capacitor continues every alternate half-cycle, maintaining the phase relation to the input sinewave shown in the block diagram. When the voltage across the stepping circuit reaches a sufficiently high value, determined by the potentiometer in the multivibrator circuit, the lefthand triode of the multivibrator conducts and the stepping circuit discharges through the diode in its cathode circuit. Thus this diode is the second electronic switch and the multivibrator is the switch control. After the stepping circuit is substantially discharged, the multivibrator returns to normal.

Versatility of Application

The circuit can be built into a compact unit and arranged so that any ordinary type of tube can be tested. A calibrated switch can be provided for changing the magnitude of grid voltage steps and a potentiometer for varying the number of steps. A small resistor with a shorting switch, placed in the cathode circuit of the tube under test, enables the operator to show the effect of cathode degeneration on the tube characteristic. Similarly, a switch in series with the screen by-pass capacitor will permit showing the effect of screen degeneration. Another potentiometer may be provided to vary the screen grid voltage of tetrode and pentode tubes.

Some interesting observations may be made if a potentiometer is connected between the screen grid and ground with the suppressor grid connected to the movable arm. As the potential on the suppressor grid is varied from a positive value to zero, the characteristic curves change from those of a tetrode to those of a pentode. This effect is shown in the accompanying pictures. There are many possibilities for additional potentiometers and switches which will make the circuit even more flexible.

One of the main applications of this circuit, its use in the design of electronic circuits, has already been pointed out. This application offers the designer a method of easily trying all possible circuit combinations in order to ascertain the best combination for a particular case. It also affords him a method for noting the effects on the characteristic curves of such things as feedback and degeneration.

In addition, an opportunity is provided for making a more detailed study of any portion of the curves by merely increasing the gain of the amplifier in the cathode-ray oscilloscope. Such an enlarged picture would be useful, for instance, in the design of low-level audio amplifiers. These amplifiers are usually operated with such low plate voltages that the portion of the characteristic curves actually required for design purposes is either not given or is too small to be of any practical value.

This circuit can also be used to obtain a full set of characteristic curves and thus check the comparative performance of new tubes during manufacture. These curves can be photographed and used for further study. If small irregularities appear on the curves, that portion of the curves on which they appear can be enlarged on the screen of the cathode-ray tube, making it easier to determine their exact nature.

Another application of this circuit is its use as a lecture-room or laboratory demonstration apparatus. It provides a positive means of demonstrating what happens to a tube's characteristic curves, and consequently to its operating characteristics, when element voltages are varied, when degeneration is used, and when various circuit parameters are changed.

References

(1) Jacob Millman and Sidney Moskowitz, Tracing Tube Characteristics on a Cathode-Ray Oscilloscope, ELECTRONICS, p 36, March 1941.

(2) E. C. Easton and E. L. Chaffee, Pulse-Type Tester for High-Power Tubes, ELECTRONICS, p 97, Feb. 1947.

VOLTMETER

Simple nomograph gives true voltage in high-impedance circuit when measurements are made with two different voltage ranges of an ordinary low-sensitivity voltmeter. Underlying equations for voltmeter error are given, with examples of use

MEASURING voltages across high - impedance circuits with voltmeters of sensitivities in the order of 1,000 ohms per volt will give readings that are appreciably less than the true voltages.

The higher the input resistance of a voltmeter, the lower will be the required deflection current and hence the smaller the error. With voltmeters of 20,000 ohms per volt sensitivity or greater, the error is usually negligible.

There are many voltmeters in use of the 1,000 and 5,000 ohms per volt class, and frequently these are the only instruments available when it is desired to know the actual voltage across a circuit.

The purpose of this paper is to provide an equation (suitable for slide rule calculations) and a nomograph (which only requires a straightedge) that will quickly yield the true voltage in a circuit after two measurements are taken with a voltmeter of low sensitivity. The only requirement of the voltmeter employed is that the internal resistance of the meter be directly proportional to the voltage range selected. All of the common type of current-operated voltmeters come under this classification.

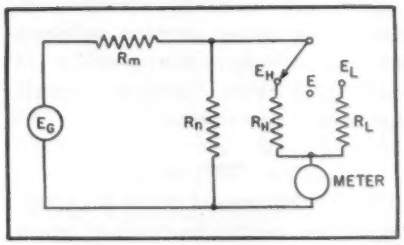


FIG. 1—Circuit of two-range voltmeter used as example

The circuit shown in Fig. 1 represents a voltmeter with two ranges connected to a simple network. In practice, circuits are usually more complex than this, but they can be reduced to an equivalent circuit similar to that in Fig. 1.

Let E = true voltage across R_n with voltmeter disconnected
E_H = voltage measured across R_n on highest meter range that will give an accurate reading
E_L = voltage measured across R_n on next lower range
E_G = source of constant voltage
R_H = internal resistance of voltmeter when measuring E_H
R_L = internal resistance of voltmeter when measuring E_L
S = ratio of two scales used; $S = R_H/R_L$
R_n = resistance across which output voltage is developed
R_m = series dropping resistance that accounts for difference in E_L, E_H, and E.

Derivation of Equation

Simple circuit theory allows us to write

$$E = E_G \frac{R_n}{R_n + R_m}$$

$$E_H = E_G \frac{R_H R_n}{R_H R_m + R_H R_n + R_m R_n}$$

$$E_H = E \frac{R_m + R_n}{R_m + R_n + (R_m R_n / R_H)} \quad (1)$$

$$E_L = E \frac{R_m + R_n}{R_m + R_n + (R_m R_n / R_L)} \quad (2)$$

Substituting SR_L for R_H in Eq. 1 and solving for E in both equations, we have

$$E = E_H \frac{R_m + R_n + (R_m R_n / SR_L)}{R_m + R_n} \quad (3)$$

$$E = E_L \frac{R_m + R_n + (R_m R_n / R_L)}{R_m + R_n} \quad (4)$$

Rearranging Eq. 3 and 4

$$(R_m + R_n)(E - E_H) = E_H \frac{R_m R_n}{SR_L} \quad (5)$$

$$(R_m + R_n)(E - E_L) = E_L \frac{R_m R_n}{R_L} \quad (6)$$

Dividing Eq. 5 by Eq. 6

$$SE_L(E - E_H) = E_H(E - E_L)$$

$$E = \frac{(S-1)E_H}{S - (E_H/E_L)}$$

This equation is particularly suited to slide rule calculations.

Example 1: A voltmeter, when placed across two terminals, reads 105 volts on its 200-volt range. The meter is switched to the 100-volt range and reads 70 volts. Divide 105 by 70 and subtract the quotient from the scale ratio of 2.0. This gives us 0.5 for the denominator. It should be noted at this time that when the scale ratio is 2.0, the term $(S - 1)$ in the numerator equals 1.0. Now divide 105 volts by 0.5 and the result is the true voltage of 210 volts.

Example 2: A voltmeter reads 50 volts on its 150-volt range. On the 60-volt scale it reads 40 volts. $E_H/E_L = 50/40 = 1.25$. Subtract this from the scale ratio of 2.5 and the denominator equals 1.25. Divide this into E_H (50 volts) and multiply the quotient by $(2.5 - 1)$ or 1.5. The true voltage is 60 volts.

Use of Nomograph

Although this equation is not difficult to use when one has become familiar with it, still it is less trouble and quicker to lay a straightedge on a nomograph and read the unknown value directly.

The nomograph presented in this paper is divided diagonally into two parts. Each half is used in the same way. The graph was divided to facilitate reading the four scales for $S = 5$, 2, 4, and 2.5. These values of S were chosen after 26 volt-ohm-milliammeters of 10 manufacturers were examined for their most

LOADING

By R. E. LAFFERTY

Chief Engineer, WSLB and Radio Instrument Laboratories
St. Lawrence Broadcasting Corp.
Ogdensburg, New York

popular switching ratios of both d-c and a-c ranges. The favorites are 5 and 2, with 4 and 2.5 used least. The ratio of 10 was used so seldom that it was not included in this nomograph.

As in the case of the equation, the best way to explain the use of the nomograph is with example problems. To compare the results of the equation with that of the nomograph, use the same problems as before.

Example 1: $E_H = 105$ volts and $E_L = 70$ volts. Place a straightedge between these values on the E_H and E_L scales for $S = 2.0$ and let it extend to the E scale. The straightedge will pass through 210 volts on the E scale, which is the true voltage. Note: This lower right half of the nomograph is also used when $S = 5$. Since values here are beyond range of nomograph, values on all three scales were multiplied by 10.

Example 2: $E_H = 50$ volts and $E_L = 40$ volts. This solution requires the use of the upper left half of the nomograph since $S = 2.5$. Using the scales for $S = 2.5$, with all scale values multiplied by 10, the true voltage is found to be 60 volts on the E scale.

The equation and nomograph will yield the true voltage only when the measurements are taken across linear circuits. Should lowering the voltage, due to voltmeter loading, change the network resistance, the nomograph can not be used.

The question arises as to how well the nomograph will apply to vacuum-tube circuits. Placing a current-operated voltmeter between a tube element and ground will lower the voltage on that element. Experiment shows that when the tube is operated with fixed bias the element resistance changes considerably with changes in element potential and the nomograph should not be used.

When cathode bias is employed, the reduction in voltage is accompanied by a proportional reduction in current. Thus the resistance of the tube remains substantially constant within the normal limits of operating voltage for the tube. In this instance the nomograph may be used, but with reserve. The resulting error is usually less than 5 percent but higher errors have been encountered. However, the error before using the nomograph was in some cases as high as 60 percent.

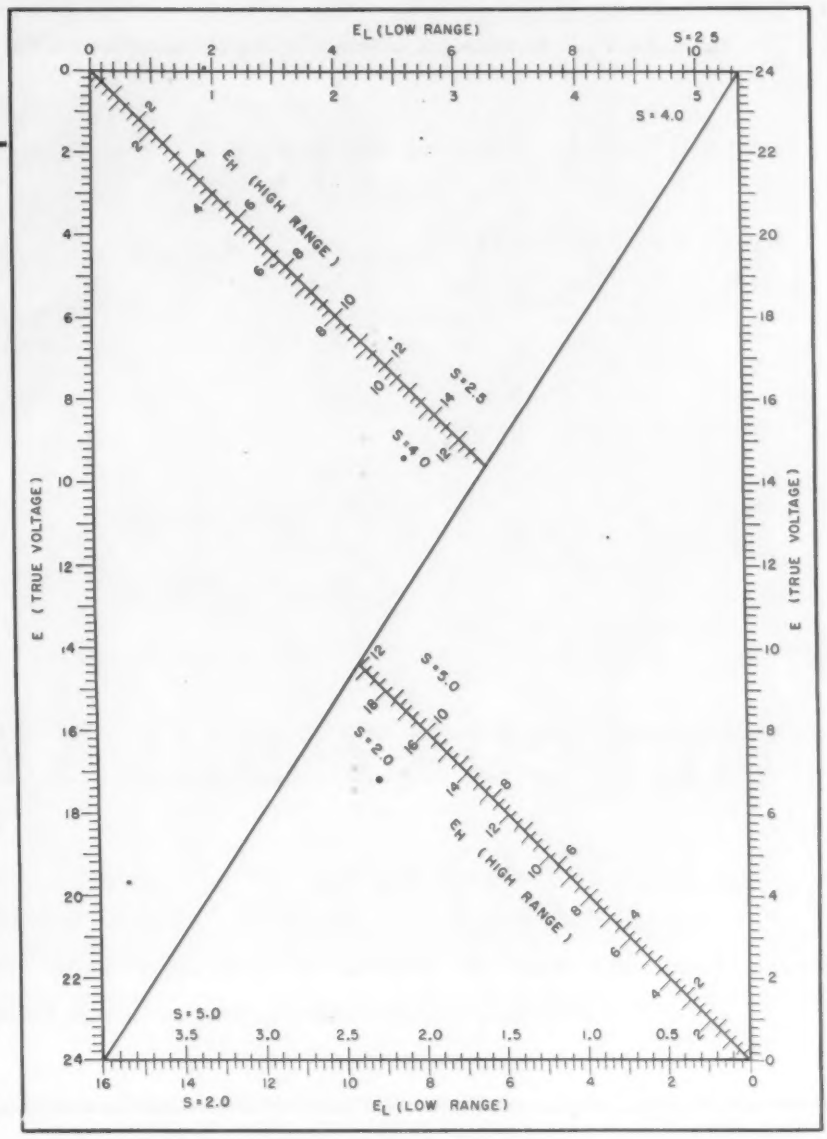
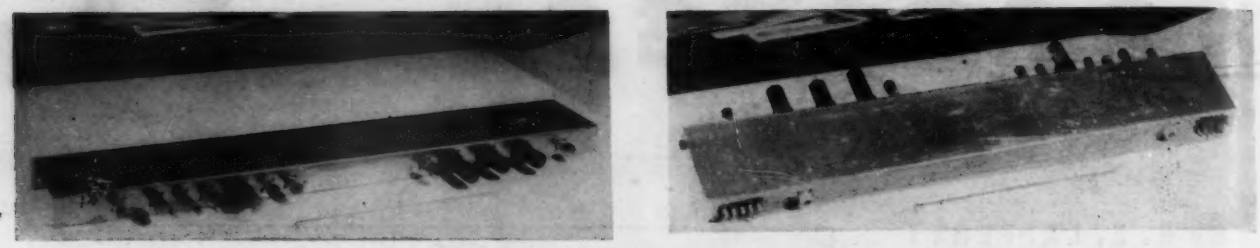
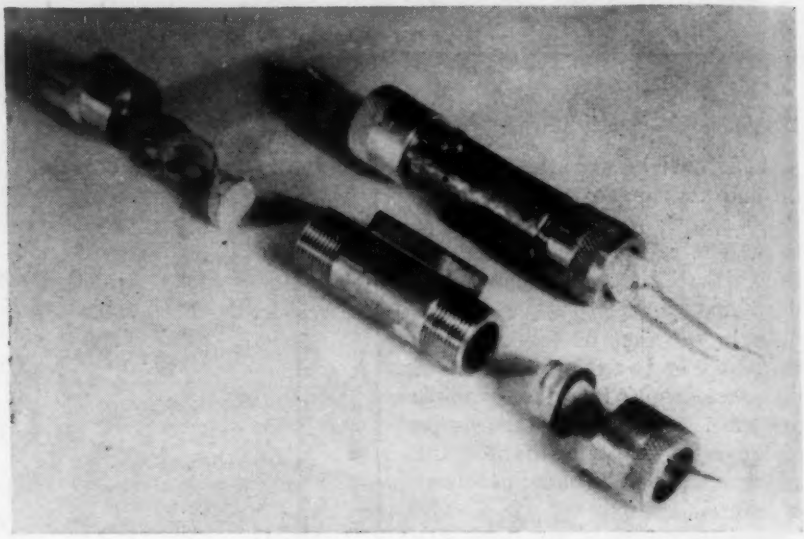


FIG. 2—Voltmeter loading nomograph. Take voltage readings on two ranges, divide higher range scale by lower to get S (either 2, 2.5, 4, or 5 on standard volt-ohm-milliammeters), then place straightedge on measured values (E_L and E_H) for S scale in question and read true voltage on adjoining E scale. If range of any scale is inadequate, multiply all scale values by 10, 100, or any other convenient factor



Amplifier and gate for memory is compactly constructed on channel that plugs into computer for quick servicing

By T. K. SHARPLESS
Chief, Digital Computer Section
Moore School of Electrical Engineering
University of Pennsylvania
Philadelphia, Pa.



This 2-inch long mercury line introduces about 40 microseconds delay

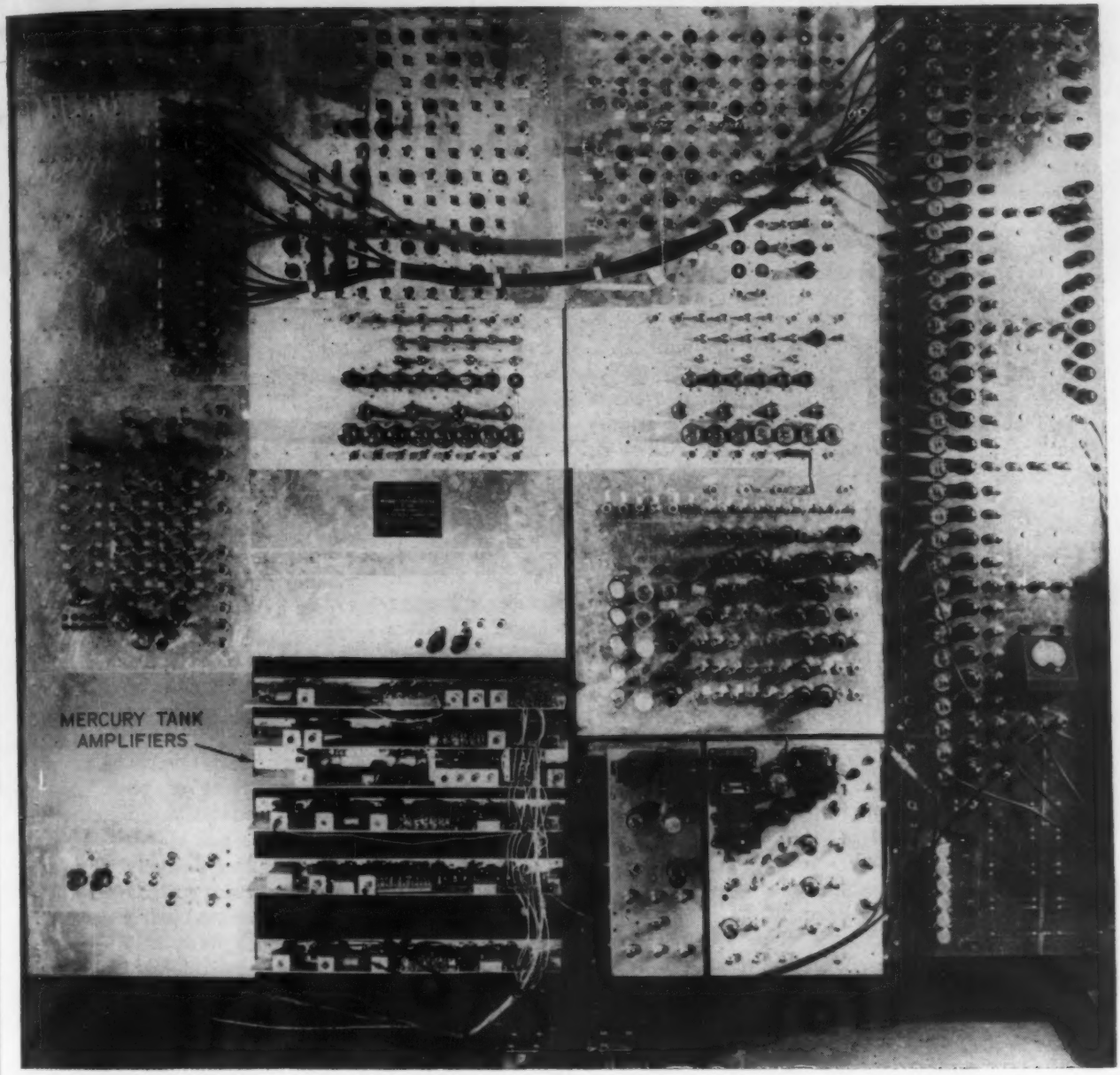
Design of MERCURY DELAY LINES

Mercury is used to obtain millisecond delays for radar, computers, and memory devices because it transmits compression waves relatively slowly, introduces negligible loss, and has an impedance comparable to that of crystal transducers. Recirculation and temperature compensation techniques are presented

STORING information and timing events are two applications of electronics that have recently become important. Electronic timers for providing oscilloscope and radar indicator sweeps, and image storage tubes that retain patterns for protracted periods are familiar devices that perform these functions. The mercury delay line is a basic component that also performs these and many related useful functions.

The line consists of a column of mercury in a container. At one end of the column is a quartz crystal that is connected to the electrical circuit of which the line is a part. Electrical pulses from the circuit vibrate the crystal sending ultrasonic wave trains down the mercury column. The wave trains are reflected at the far end of the line and return to the crystal where they are converted into electrical pulses and re-enter the circuit. A second crystal can be used at the far end of the line instead of the reflector, or multiple reflections can be used. The mercury delay line can be used in any circuit requiring delays of hundreds of microseconds with rise times in the order of 0.05 to 0.1 microseconds.

Before analysing the time delay action of the mercury line, it is well to review a few special examples of its applications. Timing of sweeps is one of the first uses to which the mercury line was put. When a repeating time base, such as that used for range measurement in ra-



Mercury delay lines are installed in heavy thermal-conducting holders behind this pilot model of the 3,000-tube EDVAC automatic computer. The final model will use mercury lines in glass tubing about 2-ft long, providing 384 microseconds delay

dar, is required, it can be generated by triggering a sweep oscillator and simultaneously applying the triggering pulse to a mercury line. The pulse traverses the line in a certain fixed time and reappears to retrigger the sweep generator, and is again applied to the mercury line. Because the mercury line always delays the triggering pulse for the same interval, the sweep repeats itself with extreme regularity. The delay is proportional to the length of the mercury line[1].

Mercury lines are also used for storage. A pulse fed into the line or storage tank remains in it for a predetermined period, dependent on the length of the mercury column.

Inasmuch as this storage function is similar to the mental process of remembering, it is referred to, especially in connection with automatic computers, as memory. In these computers the result of one manipulation, forming a portion of an extensive computation, is required in a subsequent manipulation. In such cases, the signal that is to be re-used, usually a binary pulse sequence, is fed to the mercury memory tank. The line is made of a length that will store or delay the required amount of signal until the time when it will be re-used in the computation[2].

Data Storage in Digital Computers

Experience with large scale computing machines indicates that the most important problem to be

solved in their design is that of providing high speed information storage. Moreover, if a suitable low cost memory can be developed, all information, both numerical data and routine intruction may be stored in the same medium and, indeed, in the same organ. If such a memory were provided, the question of how much problem and routine storage must be provided reduces to the question of how much total storage is required. In addition, a single organ for all storage opens the possibility for the machine to perform logical and arithmetical operations on its own instruction, thus greatly increasing its generality. The mercury line provides such storage at a cost of approximately ten cents per binary digit.

Storing Pulse Chains

The system of storage used with delay lines depends upon timed distribution of the electrical impulses that represent the information, called time division in communication circles. The coding of the pulses in this application is of no consequence except that it is assumed that the presence or absence of the pulse are the only indications possible in each time position. Figure 1A shows a typical "word" of five pulses; T represents the pulse spacing in time, and p the pulse width.

With information in the form of pulse chains, a possible method for storing or remembering the data is to insert the timed series of pulses into a suitable delay medium that requires a duration W for one pulse to traverse its length. Thus there is trapped in the delay at any time W/T pulses. If the output of the delay line is fed back to the input, through suitable amplifiers and pulse shaping circuits, as shown in Fig. 1B, the data is trapped and circulating, ready to be called out when needed.

The primary design limitation of the delay storage line is its high-frequency response or rise time of the circuits. For, clearly, the higher the repetition rate of the pulses, in other words the smaller is T, the more information can be stored in a given delay W. The next factor in importance is the amount of loss in the delay medium itself, for loss limits the length W that can be employed. Along with this factor, consideration must be given to overall physical size. Thirdly, the delay must be fairly constant with such factors as temperature, pressure, and humidity. Fourthly, it must be possible to properly terminate the delay line to prevent reflections from bouncing back and forth. Finally, it should be possible to build the device relatively easily and cheaply and yet have a rugged, reliable piece of equipment. The mecury line satisfactorily meets all of these requirements.

Ultrasonic Delay Lines

Mercury is used as the transmission medium for several reasons. Being a liquid it has a relatively low acoustic velocity and also will transmit only one mode of vibration, namely compressional waves. Moreover, the acoustic impedance of mercury is high, of the same order of magnitude as that of quartz and other crystals suitable for use as electromechanical transducers at high frequencies, so that adequate coupling can be obtained. Mercury also has low attentuation per unit length up to frequencies in the order of ten megacycles.

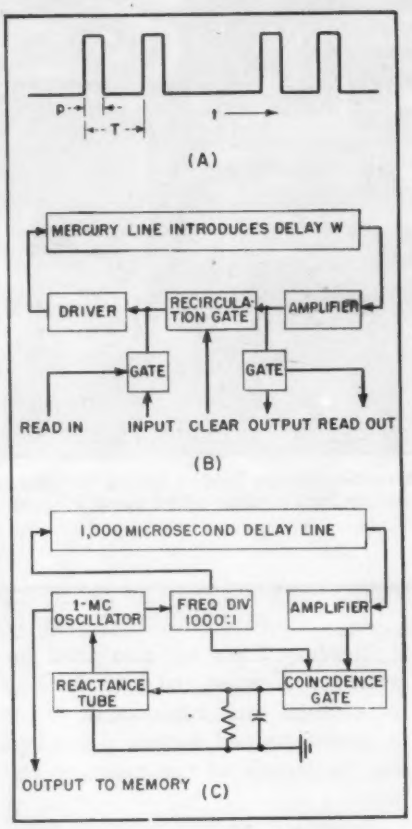


FIG. 1—For use with delay lines, information is in the form of pulse chains (A). These chains can be recirculated (B) through gates and the line so as to be stored as long as necessary. To compensate for temperature effects on the mercury lines, a timing oscillator (C) can be frequency controlled by an auxiliary line, the output being used to time pulses to the bank of mercury memories

Compressional acoustic velocity in any medium is $V=(E/\rho)^{\frac{1}{2}}$ where E is Young's modulus and ρ is density. For mercury at 20 C, the velocity of the wave is 57,100 in. per sec, corresponding to a time delay of 17.52 microsec per in. Acoustic impedance of any medium is $Z=\rho V$, giving, for mercury at 20 C, 19,700 acoustic ohms per square cm. The attenuation of a rectangular pulse of 0.25 to 0.5 microsec duration applied at the driving crystal is 1.9 db per ft. measured at 20 C. The attenuation for sinewaves, including wall effects of 0.5 in. inside diameter tubing, is $0.012f^2$ db per ft. where f is measured in megacycles. The temperature coefficient of time delay is 0.0003 microsec per microsec per deg C.

A delay line designed from these parameters and suitable for storing 40 pulses spaced one microsecond apart was built in a 2-in. piece of stainless steel tubing 0.5-in. inside diameter. Knurled caps at each end hold the end cell assemblies in place. These end cells consist of 7.5-mc X-cut circular quartz crystals each soldered to ceramic end pieces to which the leads are soldered. The rise time on the line is limited by the time thickness of the crystal driver and is about 1/30 microsec.

There are two principal sources of loss: a voltage loss of 400 resulting from the limitations of the piezoelectric effect, and a transmission loss in the mercury, which is negligible for this short line. Because a gain of slightly over 400 is fairly easily achieved even at these frequencies by means of electron tube amplifiers, the losses are not very important.

Although the delay through mercury depends on temperature, variations from that factor are very

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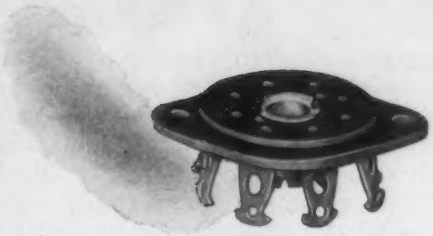

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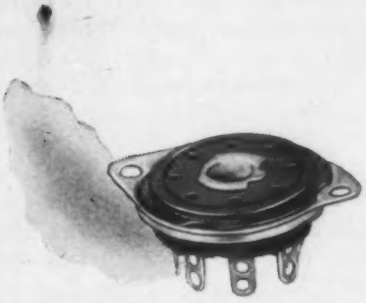

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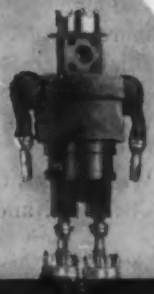

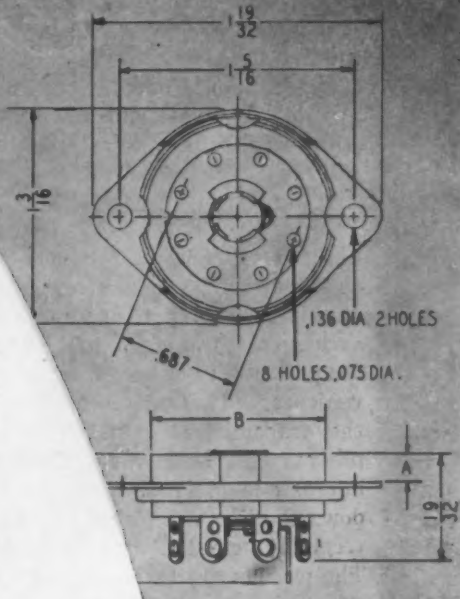

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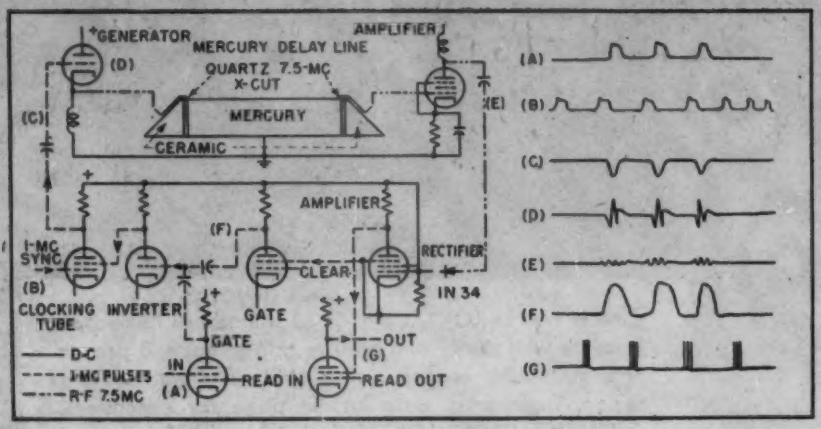

FIG. 2—Waveshapes at critical points throughout the recirculation mercury memory are shown at the right

small, one part in 3,000 per deg C. The quartz crystal matches the impedance of the mercury very closely, giving a reflection coefficient of only 12 percent. The quartz-ceramic match is practically perfect, and in addition, the ceramic end pieces are cut at an angle to break up the back wave eliminating its reflection. The construction of the line is simple and straightforward, as this brief description indicates.

Auxiliary Circuits

Figure 2 shows a complete unit as set up in the laboratory. This circuit held groups of pulses for as long as three days, after which the pulses were cleared out for convenience. The pulses applied to the transmitter crystal (D) are packets of 7.5-mc waves about 0.3 microsec long. These packets travel down the line, are picked up by the receiving crystal, and amplified. The packets are then rectified by a germanium crystal and the pulse envelope again amplified to a level sufficient to operate the recirculation gate tube and the output gate tube. The pulses then proceed through an inverter tube to the clocking or synchronizing gate tube. Here coincidence with a standard synchronizing pulse each microsecond produces a standard pulse at a fixed time that drives the 7.5-mc oscillator or packet generator, starting a new cycle. The clocking is very important because it keeps the pulses in step as well as preventing degeneration of the pulses over a number of circulations.

The waveshapes at various points throughout the experimental circuit are also shown in Fig. 2. A group of three pulses is sent into the tank (A). The standard clock pulses (B) coincide with the three stored pulses to produce pulses (C) that drive the packet generator. The output of the generator (D) traverses the mercury line and is amplified giving pulses (E) that are rectified and re-enter the gating circuit. The pulses are then ready to be relocked (F) or they can be drawn out of the tank (G) as remembered data. (The time base of the output pulses (G) is to a different scale than the others so as to show several groups of three pulses spaced 40 microsec apart, illustrating the storage of several pulse groups.)

Temperature Compensation

Because direct transmission losses in the mercury column are small, it would seem feasible to extend the length of the line to hold many more than 40 pulses. The major practical limitation to this extension is that of delay variations with temperature. With a ± 0.1 microsec tolerance, a tank 1,000 microsec long would have to be kept within ± 0.3 C. To keep a group of tanks at a temperature fixed within these limits is a difficult, though not impossible, job.

If a tank is used to establish the frequency of the pulses, in other words—their spacing, it becomes necessary only to keep all tanks at the same temperature ± 0.3 C. A block diagram of an automatic frequency control unit for this purpose is shown in Fig. 1C. A 1.0-mc oscillator is tuned by a reactance tube whose control voltage is obtained from the coincidence of a pulse from a dividing counter. A single pulse is delivered to the tank when the counter starts counting the pulses that are coming from the oscillator.

For storing N pulses in a tank, one uses a tank of NT length at a given temperature and an N-stage counter. In this case N is 1,000 and T is 1 microsec at 20 C. At the end of 1,000 microsec the pulse emerges from the tank and the 1,000th pulse leaves the counter. These two pulses are fed to a coincidence tube whose output voltage is used to control the frequency of the oscillator and hence the pulse spacing is adjusted to keep 1,000 pulse spaces available in a similar tank at similar temperature.

The temperature compensating system has been set up in the laboratory and has proved capable of control over a temperature range of 45 C. All the tanks are kept within ± 0.3 C by mounting them all on a thermally conductive base that prevents sizable thermal potential differences between them. Also, care in placing the memory cabinet will remove thermal sources and sinks.

The mercury delay memory tank appears to be such a promising device that plans at the Moore School include a future large scale digital computer using this memory means. It is hoped that within a year such a machine will be an actuality; a machine that will have a high speed memory equivalent of 1,000 ten-digit numbers, computing speeds somewhat faster than the ENIAC, and employing only 3,000 tubes. The mercury delay tank described in this paper is the result of many peoples' efforts. Among those whose contributions are known to the author are J. P. Eckert, Jr., J. W. Mauchly, C. B. Sheppard, Joseph Chedaker, and Herman Lukoff.

References

(1) L. N. Ridenour, "Radar System Engineering", McGraw-Hill Book Co., p 667, New York, 1947.
(2) Mercury Memory Tanks in New EDVAC Computer, ELECTRONICS, p 168, May, 1947.

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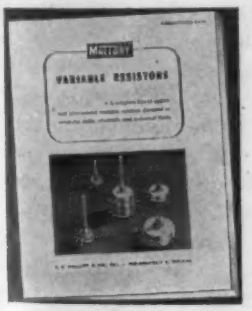

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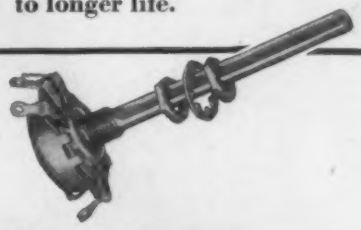

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Electrically Controlled Permanent Wave Machine..... 140
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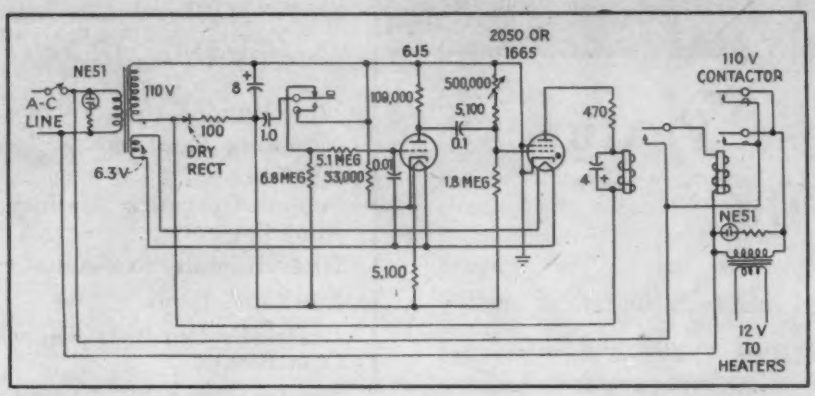
Electronically Controlled Permanent Wave Machine

BY EUGENE W. NELSON
Detroit, Michigan

AN ELECTRONIC permanent wave machine, known to the beauty culture trade as the Flash Wave, is said to effect important economies in the operation of beauty salons and promises better service to the customers of these shops. The machine and the permanent wave solution used with it for waving hair are the products of seven years of research and testing.



Timer circuit for automatic control of heat from the permanent wave machine

Electrically controlled Flash Wave in use. The box on top of cabinet contains the electronic controls of the machine made by Vernan Mfg. Company, Johnstown, Pa.

Sixty-cycle current from the line is stepped down to 12 volts at about 35 amperes and is applied to the lightweight insulated plastic "heaters" in which are placed the prepared curls of hair. Control of the heating current is done by an electronic circuit which offers a completely automatic means of utilizing the advantages of high heat without the danger of over-processing the hair as would be the case without such controls. Its circuit is shown in the diagram.

Steam-Heated Curl

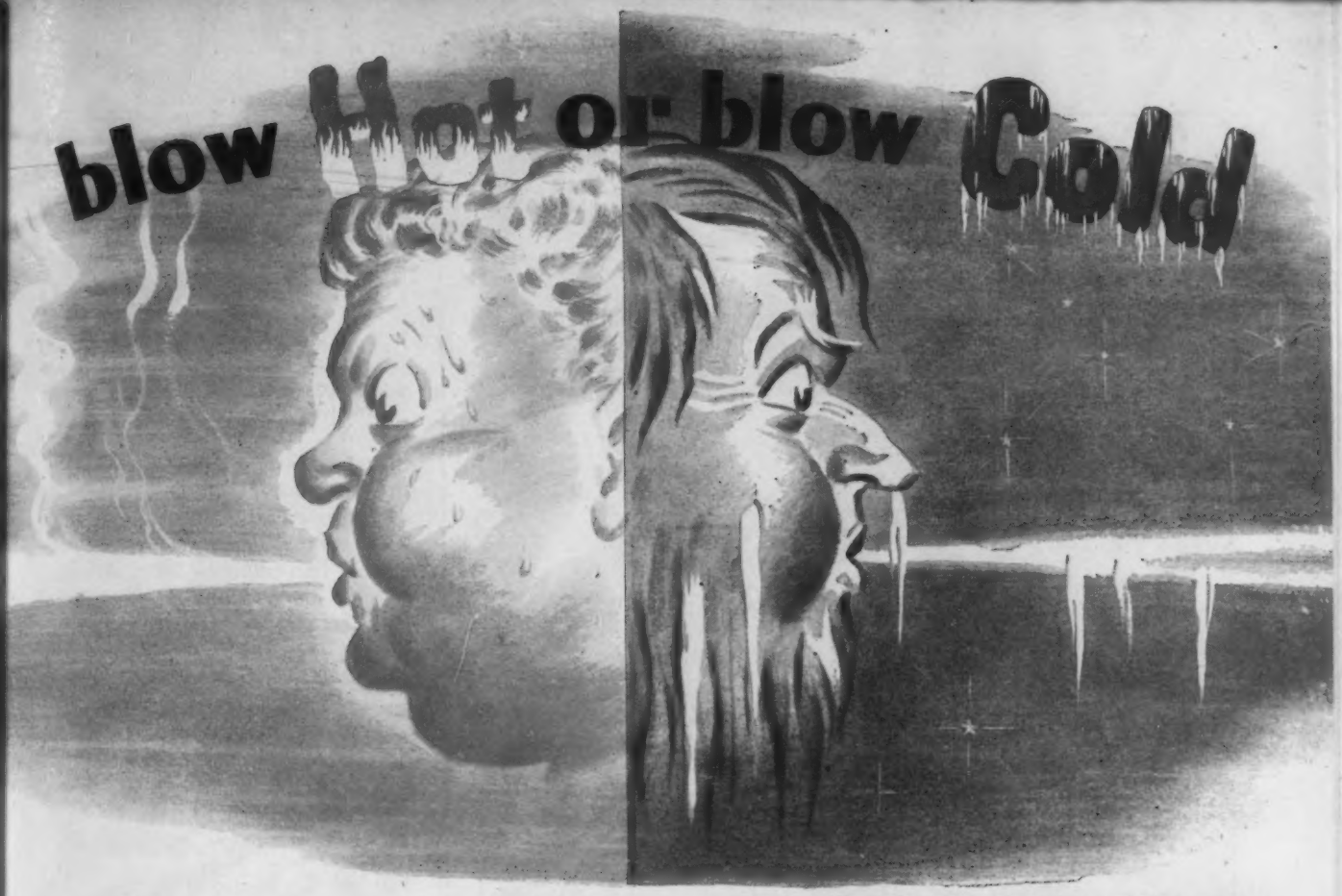
The heaters used with the Flash Wave machine are closed at each end. Thus the steam which is instantaneously generated by the intense shot of heat acting on the permanent wave solution with which each curl of hair is treated is retained (under negligible pressure) around the curl.

Conventional permanent wave machines apply heat much more slowly than does the Flash Wave. Thus, the steam inside the individual heater is generated more slowly than in the electronically-controlled machine and the moisture created by vaporization of the wave lotion is dissipated almost as rapidly as it is formed. Consequently, the hair may dry out and become brittle. In addition, most of the heaters used on conventional machines are open at each end, instead of being closed as in the Flash Wave. The open ends help the drying process.

Application of Flash Wave heat to the hair lasts from as little as 5 seconds to as much as 20 seconds. Actual duration of the heat depends upon condition of the hair. Normal hair requires a shot of heat lasting from 7 to 10 seconds.

After the proper application time has been determined by a test curl, the electronic controls are set and connection is made to each heater. The machine is also equipped with safety devices which prevent any current from flowing unless all parts of the apparatus are functioning perfectly.

Reports from the field indicate that six permanent waves can be given in a single hour with this



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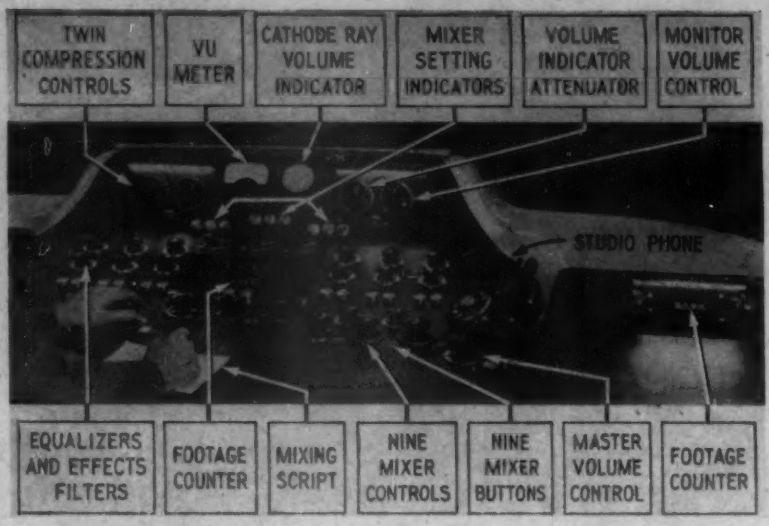
The Front Cover—Console for Dubbing



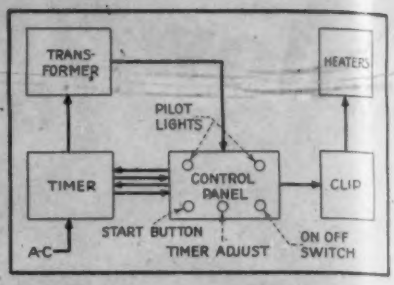
A SOLUTION to the problem of mixing the outputs of up to nine different sound channels while watching a slidefilm or motion picture in a darkened projection room is pictured on this month's cover. Taken at Reeves Sound Laboratories, New York City, it shows their new recording console that can accommodate up to four persons without crowding, as required for introducing, combining, and fading out narration, background music, and sound effects smoothly at precisely correct instants during production of the final sound track or master record.

For each channel there is a mixer control, linked to a numbered tape indicator on the volume indicator panel so that the operator can see at a glance the level settings of all channels and can set each channel to the precise level called for on the cue sheet. Each channel has twin equalizer controls to permit accentuation or attenuation of low and high audio frequencies separately. Switch-controlled twin filters provide varying low and high-frequency cutoff over a wide range as required for such unusual effects as simulating telephone conversations or the tone of an old orthophonic phonograph. Selective volume compression controls operate on a split-channel basis to permit nondiscriminative compression adjustments. Twin master mixer potentiometers are provided for split-channel operation. Remote indicators for all mixer controls are illuminated from the rear in such a way as to show red when the mixer is keyed off; operation of the mixer key changes the illumination from red to white, and the white illumination increases in intensity as the mixer control is advanced.

One of the two volume indicators is a conventional illuminated-scale high-speed type reading in vu, while the other is a unique cathode-ray instrument that shows on its screen a duplicate of the actual sound track as it is being recorded. Distortion and track modulation are thus indicated to the operators at all times.

All static sound channel units are remotely located. Elimination of preamplifiers in this way insures prevention of objectionable microphonic noise during recording.

An illuminated footage counter on the panel furnishes an exact check on film position and length, allowing the mixer operator to record vital timing cues on his mixing script. Side panels for the film editor and director have similar footage counters. Fluorescent strip lamps on the console provide ample illumination of controls when the room is darkened for projection.



Block diagram of the electronically controlled permanent wave machine

electronically-controlled machine. In addition, there is almost no heat dissipated to either customer or operator; heaters can be removed immediately after application of heat with no time wasted in cooling before removal; and operation requires no special training on the part of an operator who is already experienced in standard techniques of giving permanent waves.

Tracking the Permeability-Tuned Circuits

By A. W. Simon

Assistant Professor of Applied Mechanics
Washington University
St. Louis 5, Mo.

In a previous article[1,2] the author has given simple formulas for the calculation of the padder and trimmer coils required to reduce to a minimum the mistracking between the oscillator and r-f sections of permeability-tuned superheterodyne receivers. By the application of these formulas, the maximum deviation due to mistracking between sections can be reduced usually to less than 1 db.

There is another cause of mistracking, namely, the reactance coupled into the r-f section by the antenna circuit. While the effect of this reactance is not serious in the case of a rod or wire antenna, it becomes quite marked for the now widely used loop antenna, due to the higher degree of coupling used. However, the reasoning which underlies the deduction of the above mentioned formulas also suggests how the effect of the antenna circuit can be neutralized.

The basic principle of the permeability-tuned circuit is that the inductance of the respective ganged

(continued on p 156)

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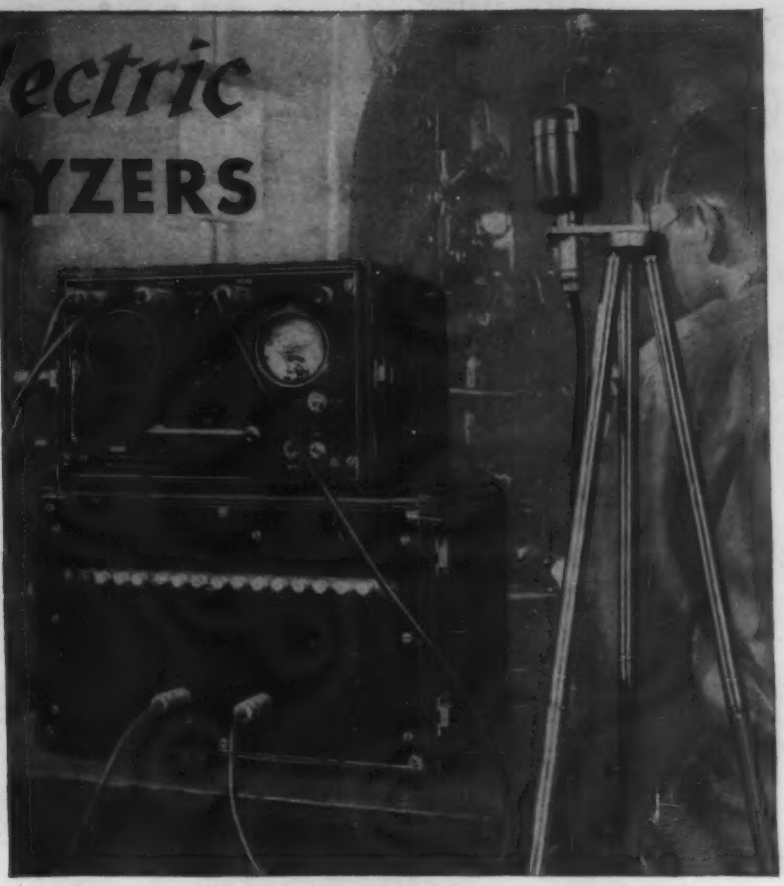

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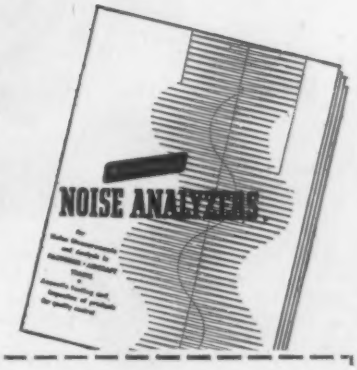

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THE ELECTRON ART

Edited by FRANK ROCKETT

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Electron Linear Accelerator Demonstrated 144
Improvements in Small Tubes 144
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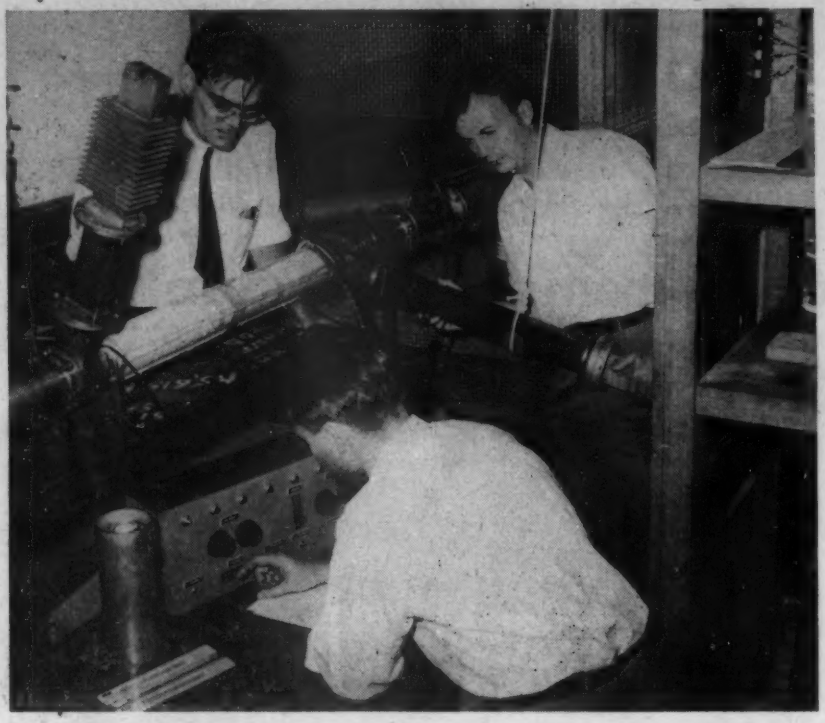
Electron Linear Accelerator Demonstrated



A 3-ft long waveguide lined with gold-plated disks, which retards 4-cm microwaves to a velocity equal to that of the injected electrons, accelerates electrons to within 99 percent of the free-space speed of electromagnetic waves, giving the electrons an apparent mass 2,000 times their rest mass and an energy of 1.5 mev. The electrons, traveling with the wave, are accelerated by its potential gradient. The accelerator, described by Dr. William W. Hansen (left) at the IRE west coast convention, is to be extended to 20 ft in the basement of the Microwave Laboratory at Stanford University. This size presents no problem in shielding against radioactivity, and will provide experience for building the final 100 to 200-ft model that will develop 1,000 mev electrons. The accelerator will make available artificial cosmic rays corresponding to fairly energetic natural rays, and thus simplify investigations now conducted in flying laboratories. The accelerator is excited for a millionth of a second every sixtieth of a second from a one-megawatt magnetron. It is hoped that the final model can use 1,000 megawatts. This accelerator is simpler and cheaper than a synchrotron, and, using light-weight electrons instead of heavy protons as in cyclotrons, can produce higher-velocity particles, with which much information about the constitution of the electron can be gained. Dr. E. L. Ginzton, of the physics department faculty, and postgraduate students in physics, William Kennedy (center) and Richard Post (operating controls), are assisting in the development that is being sponsored by the Office of Naval Research

Culturing Crystals

Pilot production paved the way for quantity culturing of synthetic piezoelectric crystals

PIEZOELECTRIC CRYSTALS, artificially cultured by Western Electric Co. using techniques developed by Bell Telephone Labs. will replace about 90 percent of the natural quartz in the telephone system in a few years. The artificial crystals, ethylene diamine tartrate, although differing chemically from natural quartz, are piezoelectric and so are cut into plates and gold coated to form crystal filters. (Synthetic piezoelectric crystals for sonar, developed during the war to meet the tremendous need for transducers, were ammonium dihydrogen phosphate.) In commercial production, the artificial crystals weigh about a pound, are six inches long, and two by three inches in cross section. Seeds of crystals, about a third of an inch across, are first grown by evaporation of a saturated solution of the chemical. The seeds are then constantly slowly washed by a supersaturated solution, the temperature being kept within a tenth of a degree. With this production technique a crop of crystals can be harvested every three months.

Improvements in Small Tubes

COMPACT, mechanically dependable electronic equipment requires small tubes of exceptional characteristics. Recent developments have produced smaller and less microphonic tubes. For example, the Victoreen Instrument Co. has changed the construc-

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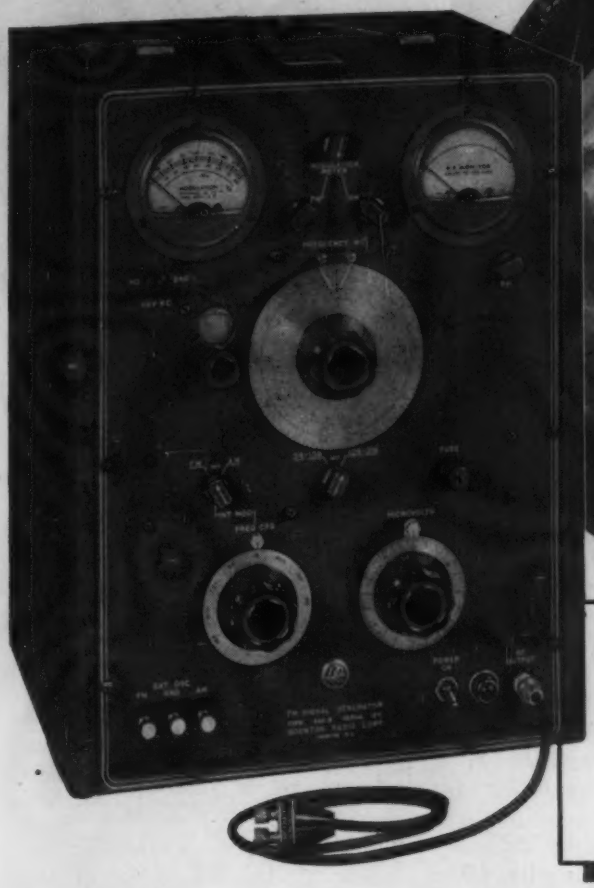

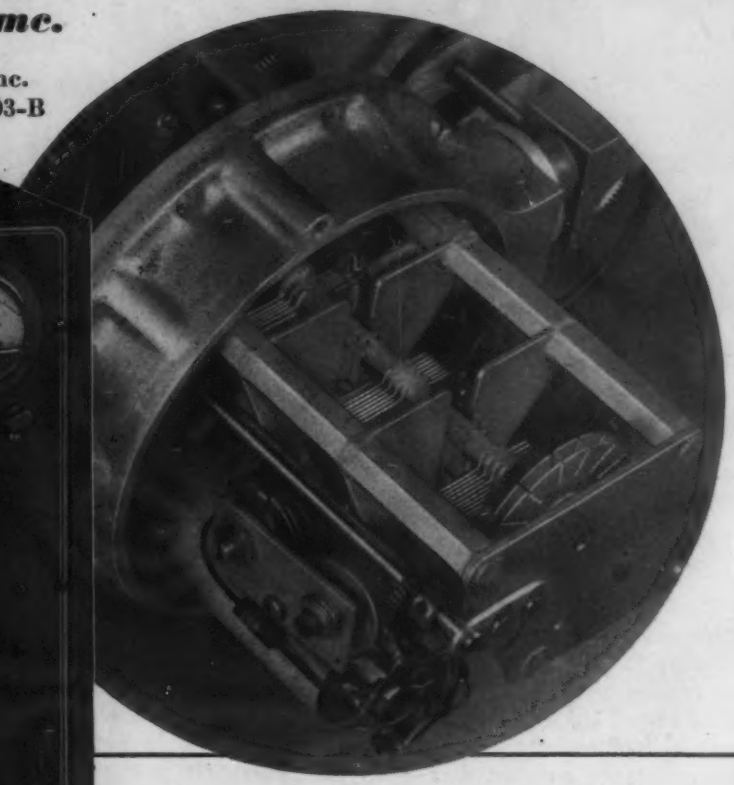

Shown above is an interior view of the 202-B Signal Generator RF assembly with shield cover removed. Heavy aluminum castings form the mounting base of this RF unit resulting in a compact and highly rigid structure. Girder type condenser frame construction, multiple rotor shaft grounding contacts, and welded interstage shield plates are but a few of the many design features of this unit which give added circuit stability.

Designed to meet the exacting requirements set forth by leading FM and television engineers throughout the country, the 202-B FM Signal Generator has found widespread acceptance as *the* essential laboratory instrument for receiver development and research work.

Frequency coverage from 54 to 216 megacycles is provided in two ranges, 54 to 108 megacycles and 108 to 216 megacycles. A front panel modulation meter having two deviation scales, 0-80 kilocycles and 0-240 kilocycles, permits accurate modulation settings to be made.

Although fundamentally an FM instrument, amplitude modulation from zero to 50%, with meter calibrations at 30% and 50%, has been incorporated. This AM feature offers increased versatility and provides a means by which simultaneous frequency and amplitude modulation may be obtained through the use of an external audio oscillator.

The internal AF oscillator has eight modulation frequencies ranging from 50 cycles to 15 kilocycles, any one of which may be conveniently selected by a rotary type switch for either amplitude or frequency modulation.

The calibrated piston type attenuator has a voltage range of from 0.1 microvolt to 0.2 volt and is standardized by means of a front panel output monitor meter.

The output impedance of the instrument, at the terminals of the R.F. output cable, is 26.5 ohms.

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R.F. Range: 0.4 mc. to 25 mc.

R.F. Increment Dial: ±250 kc. in 10 kc. increments.

R.F. Output: 0.1 microvolt to 0.1 volt. Also approximately 2 volts maximum (uncalibrated).

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Type 203-B

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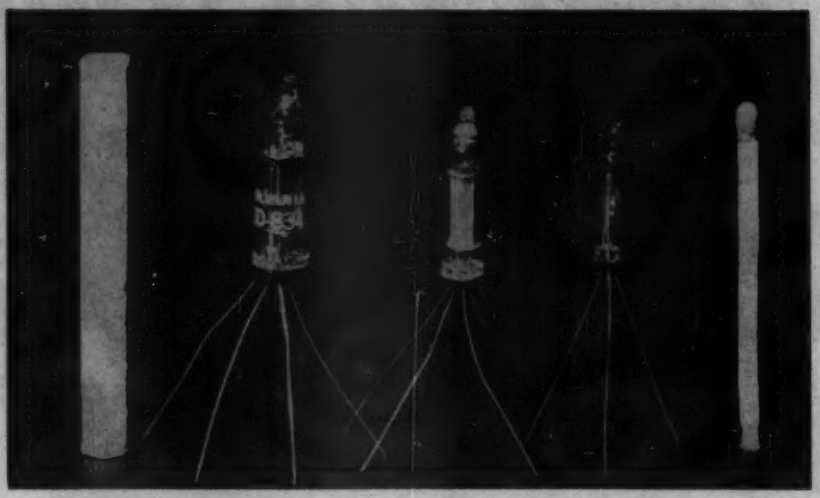

FIG. 1—Triode in T-3 bulb compares in size to cigarette; diode in T-1 bulb is approximately the same diameter as a wooden match; triode at center in T-2 bulb

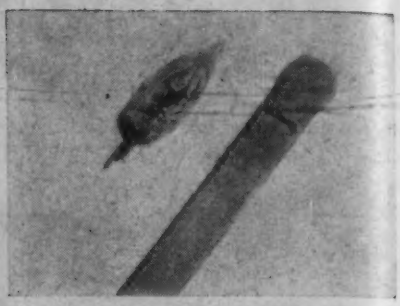

FIG. 2—Diode microtube illustrates extreme reduction in size possible for tubes

FIG. 3—Sources of microphonics are detected by vibrating tube and observing motion of internal parts

tion of their VX-41 subminiature electrometer tube (ELECTRONICS, p 106 March 1947) so that it is less microphonic and thus more widely applicable than heretofore. This tube, requiring 12.5 milliwatts of heating power, has a grid current of less than 10^{-15} ampere and a grid input resistance greater than 10^{15} ohms and yet is sufficiently stable to be used in d-c amplifiers and portable equipment.

Where power drain is not limited but space is, indirectly heated subminiature tubes (ELECTRONICS, p 154 May 1946) can be used. These tubes, using the button stem, are being made by Sylvania Electric Products in a variety of types in the T-3 bulb, some types in a T-2 bulb, and a diode in a T-1 bulb (SN-946) having the characteristics of half a 6AL5 is under development (available under allocation). Figure 1 shows the relative sizes of these tubes.

Although these tubes represent the smallest size available in any quantity, the Tube Laboratory of the National Bureau of Standards has developed an even smaller experimental microtube shown in Fig. 2. This tube, scaled down from a conventional subminiature type by successive simplifications, is a development of the basic and applied research program on vacuum tubes undertaken by the Laboratory in collaboration with industry. In such electronic devices as automatic computers where thousands of tubes are used, such tubes will represent a great saving in space.

One of the limitations to uniformity, life, and cheapness of tubes is the unpredicability of electron emission from cathodes and other elements within the tube envelope. Although the exact mechanism of cathode emission of electrons is not understood, it is recognized that such impurities in the base nickel as iron, carbon, silicon, and manganese affect the emission. The matter is so important that the American Society for Testing Materials has created a special committee with industry wide representation to study the problem.

To obtain quantitative data on the effect of any one impurity, tube manufacturers are applying stastical techniques to large samplings of their outputs. The NBS Tube Laboratory, on the other hand, is attacking the problem in the laboratory by controlled syntheses. Impurities, singly or in combinations, are deposited directly on the base nickel in measured quantities, thus isolating the variables for investigation.

Preliminary studies are encouraging, but not conclusive thus far. Other research at the Tube Lab. is directed toward preventing gas cleanup in high-current industrial relay and rectifier tubes. Apparently the major part of the cleanup in low pressure (3 to 10 microns) gas tubes is caused by ions reaching the anode at sufficiently high velocities to penetrate into the material. The gas can be driven from the anode by heating it.

Microphonic disturbances are another limitation to the operation of electron tubes, as previously mentioned. Mechanical studies made at the Tube Laboratory by vibrating tubes at various frequencies with a dynamic driver and optically observing the motion under stroboscopic light as shown in Fig. 3, are indicating how microphonics can be minimized. Two chief sources of microphonics are insecure crimping and welding of internal parts and vibration of the individual turns of the grid helix.

Whereas in amplifier tubes microphonic effects arise chiefly from a variation of the tube amplification factor as the relative grid-filament and plate-filament spacing changes, the microphonic effects in electrometer tubes, which are used in circuits in which the resistance from grid to filament is virtually infinite, arise also from the change in grid voltage accompanying variations of interelectrode capacitance produced by vibration. The effect of this

(continued on p 182)

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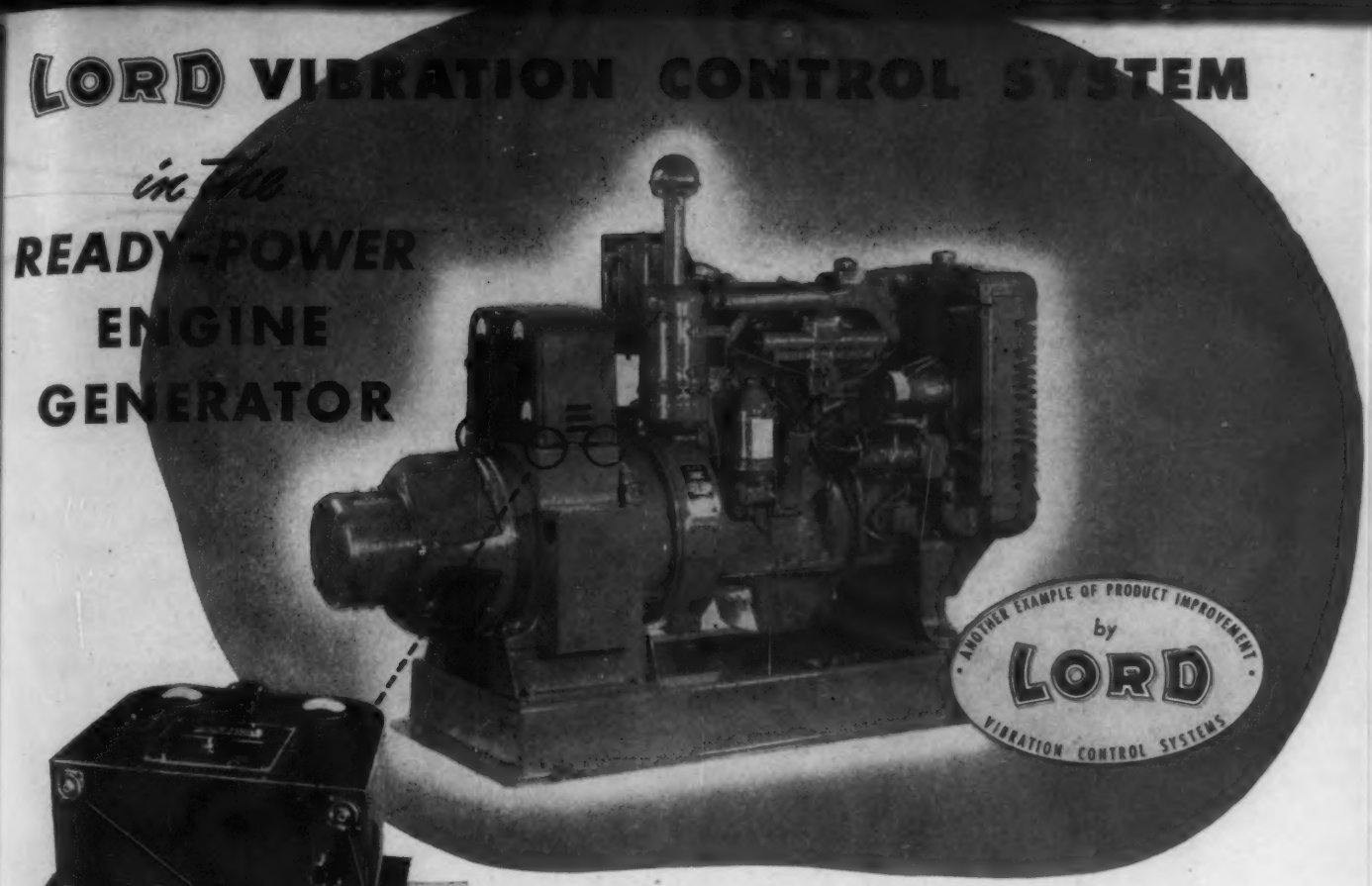

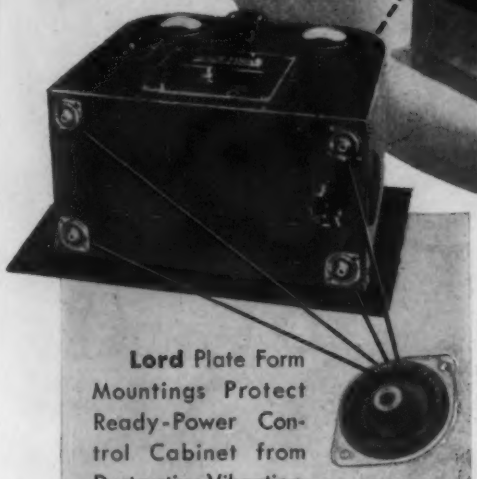

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The voltage regulator is the heart of an engine-generator set . . . it automatically eliminates extreme voltage fluctuations—maintains high quality lighting and motor efficiency.

To insure such service—plus long trouble-free life—The Ready-Power Co. of Detroit, Michigan protects this vital unit from destructive vibration with a Lord Vibration Control System. And vibration control pays off . . . in greater customer satisfaction—increased sales.

The entire voltage control cabinet is isolated from engine vibration by four Lord Plate Form Mountings in this engine generator. Simple, inexpensive—yet highly engineered—these bonded-rubber, shear-type mountings prevent the inaccuracies and failure which vibration could cause. To customers, that means lasting dependability.

Whether you manufacture engine generators or any other product, you can increase your sales by eliminating costly, destructive vibration. It will pay you to consult Lord . . . make us your headquarters for product improvement through Lord Vibration Control Systems.

LORD

MAKE GOOD PRODUCTS BETTER
with *Vibration Control*

LORD MANUFACTURING CO. · ERIE, PA.

Field Offices: Detroit · Chicago · New York · Washington, D.C.
Providence, R. I. · Burbank, Cal. · Philadelphia, Pa.
Canadian Representative: Railway & Power Engineering Corp., Ltd.

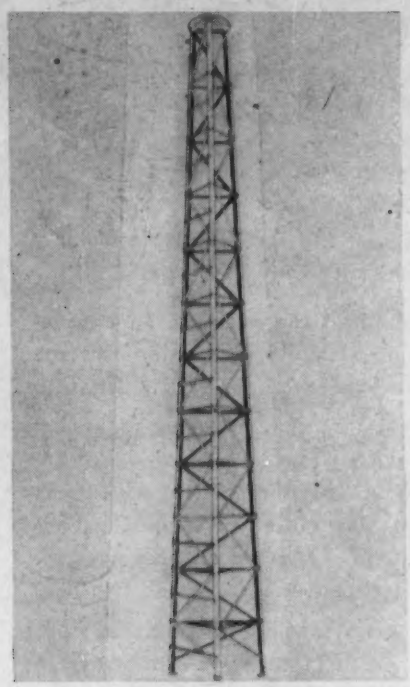
NEW PRODUCTS

Edited by A. A. McKENZIE

New equipment, components, packaged units, allied products; new tubes. Catalogs and manufacturers' publications reviewed.

Packaged Tower (1)

ROSTAN CORP., 202 East 44th St., New York 17, N. Y. The Trig tower is a selfsupporting triangular tapered structure fabricated from



61ST aluminum alloy. Delivered knockeddown, it can be erected by one man. It is designed for low cost developments in the f-m, a-m, and television broadcast fields.

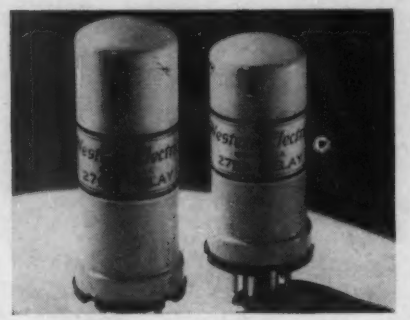
Counting-Rate Meter (2)

GENERAL RADIO CO., 275 Massachusetts Ave., Cambridge 39, Mass. The type 1500-A counting rate meter indicates directly in counts per minute the rate at which nuclear transformations occur in radioactive materials. Counting rate is shown on a panel meter, the range of operation being from 5 to 20,000 counts a minute. An adjustable and regulated high-voltage supply from

400 to 2,000 volts and a quenching circuit permit either selfquenching or nonquenching Geiger tubes to be used. Accuracy is plus or minus 3 percent of full scale on all five ranges.

Mercury Contact Relays (3)

GRAYBAR ELECTRIC CO., 420 Lexington Ave., New York 17, N. Y. Western Electric type 275 and 276 relays use a mercury-wetted contact in a hermetically sealed envelope. The units have standard octal bases and provide almost instantaneous break of contacts with high current-handling capacity. Useful in computers, sorting machines, servomechanisms, or high-speed keying systems, the relays are described in bulletin T2398.



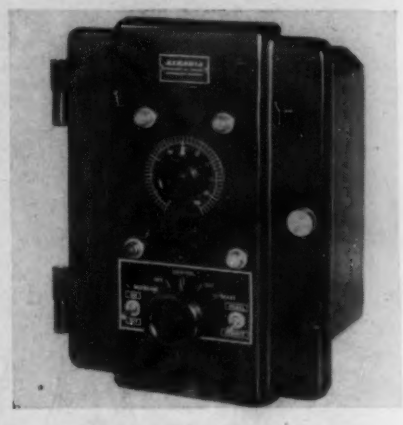
USING THE NUMBERS

Readers desiring further details concerning any item listed in the New Products department can obtain the information by using the cards furnished as a stiff, colored insert elsewhere in this department.

Place the number (appearing to the right of the heading) of one item in which you are interested in a circle and then fill out the balance of the card according to directions appearing on the colored sheet. Unnumbered items listed at the end should be procured direct from the manufacturer or publisher upon payment of the fee noted.

Electronic Servo (4)

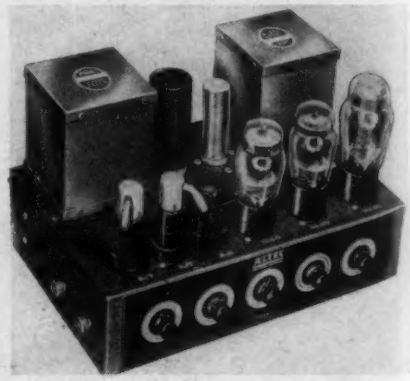
ASKANIA REGULATOR CO., 240 East Ontario St., Chicago 11, Ill. A remote control and positioning unit for valves, dampers, and other mechanical mechanisms consists of a transmitter, vacuum-tube ampli-



fier, and a receiver. Signal lamps or other audible or visual monitoring indicators can be provided. A ten-page booklet, no. 138, is available.

F-M Amplifier (5)

ALTEC SERVICE CORP., 250 West 57th St., New York 19, N. Y. Type A-323B amplifier designed for operation with f-m tuners and a good loudspeaker has built-in equaliza-



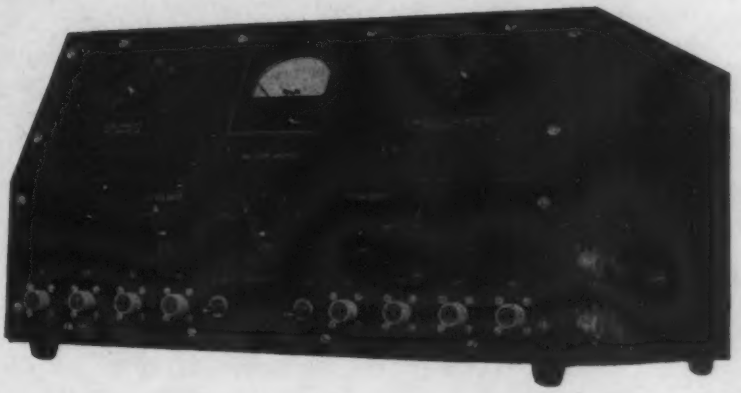
VERSATILITY *in the*

Design - Development - Production of LF, HF *and* UHF *Equipment*

For Example...

THE ELECTROMYOGRAPH

A Lavoie test instrument designed for the Medical profession. Amplifies minute potentials of the order of microvolts generated by muscles—to the extent that these potentials may be measured and analyzed. Includes calibration circuits to facilitate the taking of accurate data.



LAVOIE LABORATORIES are well prepared with trained personnel and special equipment to handle every phase of design, develpment and manufacture of LF, HF and UHF equipment. As SPECIALISTS, you are assured of precision work based on correct methods and technique developed through years of practical experience.

FREQUENCY STANDARDS • FREQUENCY METERS • RECEIVERS
TRANSMITTERS • ANTENNAS and MOUNTS

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Lavoie Laboratories

RADIO ENGINEERS AND MANUFACTURERS
MORGANVILLE, N. J.

Specialists in the Development and Manufacture of LF and HF Equipment

tion to allow direct operation from the variable reluctance or Pickering pickups. A treble tone control for use with shellac pressings is provided. There are two inputs, one for phonograph pickup and the other for radio. The amplifier is rated at 15 watts and has a frequency response within 1 db from 35 to 12,000 cycles. Response is essentially flat from 20 to 20,000 cycles.

Pulse Generator (6)

RADAR ENGINEERS, Arcade Building, Seattle 1, Wash. The type PG-5 pulse generator covers a range of pulse widths from 0.1 to 2.0 microseconds with rise and fall times of 0.05 microsecond. A positive input

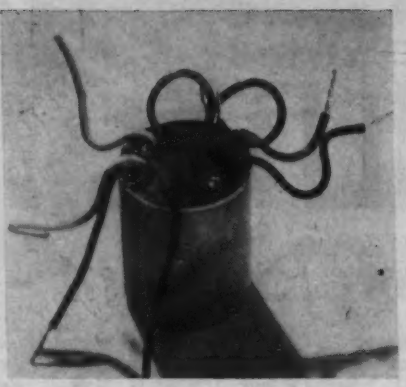
trigger of from 10 to 20 volts is required for each output pulse, the latter being variable in amplitude from minus 20 to plus 20 volts. The unit consumes 40 watts at 115 volts, 60 cycles.

Crystal Units (7)

CLARK CRYSTAL CO., 2 Farm Road, Marlboro, Mass. A new line of resonator and oscillator crystal units is announced for the frequency range 50 kc to 54 mc.

Input Transformer (8)

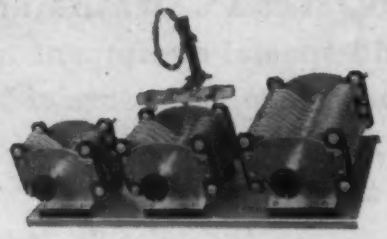
J. W. NEWTON CO., INC., 234 Seventh Ave., New York 11, N. Y. The transformer illustrated consists of two coils so wound on a specially shaped core that the unit forms its own shield in almost any position. The four windings can be



connected to give primary impedances of 500, 150, or 50 ohms. The coils can also be used in a pushpull circuit. The unit is flat within plus or minus 1 db up to 25,000 cycles. Further characteristics can be obtained from the manufacturer.

Butterfly Capacitors (9)

BARKER AND WILLIAMSON, INC., 237 Fairfield Ave., Upper Darby, Pa. Type JCX variable capacitors employ opposed stator sections and butterfly rotors that can be grounded at the center of the r-f



voltage point with respect to stators. The capacitors will handle plate potentials up to 1,500 volts.

Taxi Radio (10)

MOBILE COMMUNICATIONS CO., 202 East Fourth St., Long Beach 2, Calif. Complete main and mobile f-m vhf stations are available for taxicab two-way communications. The Taxi-Talkie system employs a lockout mechanism designed to

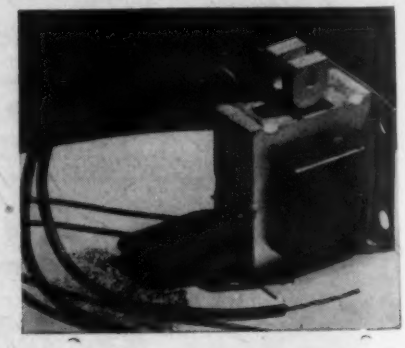
speed dispatching and yet insure a minimum of confusion among a large number of mobile units. Literature is available.

Silicone-Asbestos Paper (11)

CONNECTICUT HARD RUBBER CO., 407 East St., New Haven 9, Conn. Cohrlastic is a Silicone rubber coated asbestos paper with high heat resistance that is available in rolls 12 inches wide. It withstands temperatures in the range of 500 F to minus 70 F. It has a dielectric strength of 400 volts per mil (9,600 volts for the present standard sheet that is 0.024 inch). The material is corona resistant, will not carbon track and has good surface resistivity. Being more resilient than untreated asbestos paper, it is suitable for gasket or washer stock in applications in which compression aids sealing or holding.

All-Welded Solenoid (12)

GENERAL ELECTRIC CO., Schenectady 5, N. Y., announces a small all-welded solenoid designed for use where powerful pull is needed in a small space. It develops a maximum pull of 0.26 lb in a half-inch stroke and operates on 110 volts, 60 cycles.



Frame and bracket as well as frame laminations are all welded together. Eddy current losses are thus reduced.

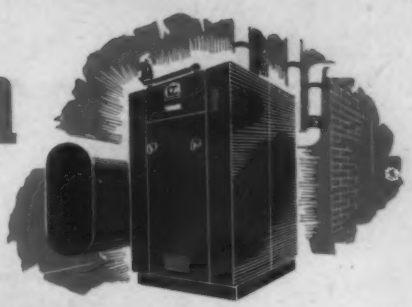
Photoelectric Relay (13)

GENERAL ELECTRIC CO., Schenectady 5, N. Y. The new photoelectric relay and light source can operate at

(continued on p 210)

Putting The Heat On

Oil Burner Coil Production



Transformer coils are wound, 14 at once on the same machine, at speeds up to 2500 rpm . . . on the No. 104 Universal Coil Winding Machines used by a company famous in the field of electronics.

No attention is required from the operator other than to load and unload. Paper of various types and thicknesses, one or two-ply, is inserted automatically . . . length of insert increased automatically . . . spindle stopped at completion of coil automatically.

OTHER FEATURES

- *Adjustable traverse mechanism—wire layer length adjustable without removing cams.*
- *Slow start — avoids wire breakage.*
- *Rapid transfer — using secondary arbor.*
- *Electric stop motion available to detect wire breaks and stop machine.*

Write for Bulletin 104. Universal Winding Company, P. O. Box 1605, Providence 1, R. I.

FOR WINDING COILS IN QUANTITY
ACCURATELY . . . AUTOMATICALLY
USE UNIVERSAL WINDING MACHINES

NEWS OF THE INDUSTRY

Edited by JOHN MARKUS

Program of Rochester Fall Meeting; network f-m and television broadcasting; pilotless ocean flight; x-ray conference; personnel items

MEETINGS

Nov. 3-5: National Electronics Conference, Edgewater Beach Hotel, Chicago. See p 240, Oct. issue for program.

Nov. 3-7: AIEE Midwest General Meeting, Chicago, Ill.

Nov. 7-8: Conference on X-ray and Electron Diffraction, Mellon Institute of Industrial Research, Pittsburgh, Pa. Program on p 254.

Nov. 17-19: Rochester Fall Meeting, Sheraton Hotel, Rochester, N. Y.; technical papers and exhibits. Program on p 154.

MARCH 22-25; IRE Convention and Radio Engineering Show, Hotel Commodore and Grand Central Palace, New York City.

Radio for Play Directors

TO TEST the usefulness of radio for communication between a television control room and stage directors in the studio, National Broadcasting Co. was granted FCC authorization for an experimental class 2 station. Since the proposed radio system will be entirely within a shielded television studio, it is not expected to cause outside interference. The frequency used will be in the Industrial, Scientific, Medical band which is available for assignment to low-power convenience radio communication.

Stage directors will be equipped with lightweight battery-operated receivers for receiving the instructions from the control booth. Heretofore this communication has been available only through use of headsets and long connecting cords plugged into various outlets about the stage.

Microwave Television Relay

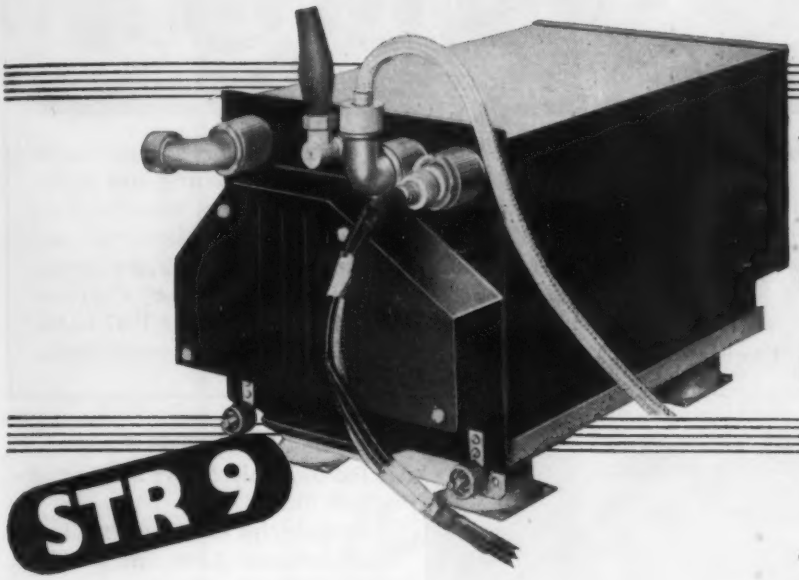
ESTABLISHMENT of a permanent microwave relay system between New York and Schenectady for a more complete programming of television station WRGB paves the way for larger audiences and more economical use of video facilities.

In a preview of the system, which was scheduled for regular operation beginning Sept. 29, engineers and the press were shown Schenectady broadcasts of programs picked up in New York from WNBT and WABD that were indis-

RMA Board of Directors for 1947-1948

lightweight • compact • built-in power-unit

Standard aircraft RADIO



V.H.F. TRANSMITTER —RECEIVER

Employing

MINIATURE COMPONENTS

and

MINIATURE TECHNIQUE

4 spot frequencies over a wide band

STR 9. A miniaturised low power-high performance transmitter/receiver designed to reduce operating to 'switch-and-talk.'

WEIGHT: 22 lb.

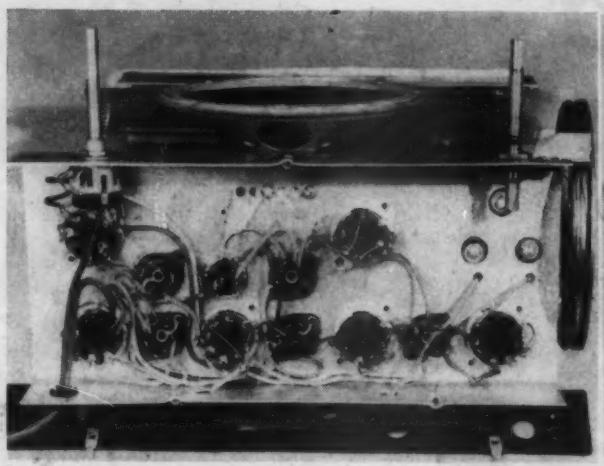
TOTAL INPUT: 180 watts at 26 volts.

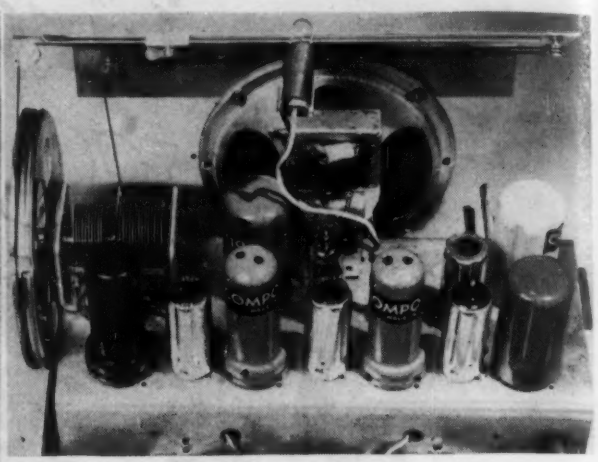
FREQUENCIES: 4 spot frequencies, remotely selected, in the band 115–145 Mc/s.

SERVICE: Telephony.

Standard Telephones and Cables Limited • TELECOMMUNICATION ENGINEERS • OAKLEIGH ROAD • NEW SOUTHGATE • N11 LONDON

Plug-in Construction Eliminates Under-Chassis Parts in New Superhet Receiver



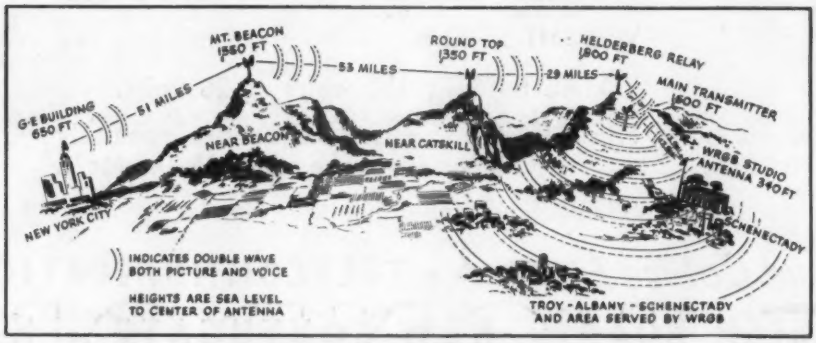


PHOTOGRAPHS here show how Cosmo Electronic Corp., New York City, achieves complete plug-in construction (except for the gang tuning capacitor) in their five-tube universal a-c/d-c superheterodyne radio receiver. Promotion will feature ease of servicing; any plug-in unit, including loudspeaker unit which screws to chassis but has plug-in connections, is to be available from dealers at price of $1.85. Each plug-in can is a different color, and purchaser of receiver gets instruction book telling how to figure out which can needs replacement when set goes bad. Filtering unit, most likely to fail, is red, and audio can is brown. Same plug-in technique is contemplated for use with Franklin Airloop Corporation's stamped wiring, described in June 1947 ELECTRONICS, p 82. One can has nine small parts inside.

tinguishable in clarity from a locally produced show.

Three unattended relay stations are required to establish line-of-sight paths shown on the map. Each receiver is in operation at all times. When the New York relay transmitter is turned on, its received signal operates the Mt. Beacon transmitter, which then energizes the rest of the chain in like manner. Although the Helderberg relay is only about 1.5 miles from the WRGB transmitter, the video and audio signals are sent to the studio control room to facilitate switching between local and remote programs. The main transmitter is fed by a microwave studio-transmitter link.

New York microwave relay transmitter (in the box) and beam antenna. Each relay receiver and transmitter is similar in appearance



New York-Schenectady television relay using frequencies between 1,800 and 2,000 mc. The New York receiving point can pick up Washington, Philadelphia, or New York station programs, which are then relayed and rebroadcast from Schenectady

Frequencies employed are in the band between 1,800 and 2,000 mc so that directional antenna gains of 1,400 are possible using 6-foot dish reflectors with a beam width of only 6 degrees. Relay transmitter power is about 10 watts.

Although the present 125-foot towers are provided with large rooms at the top for further experimentation, General Electric engineers point out that the essential relay receiving and transmitting equipment occupies a small fraction of the space. If suitable tower sites can be reasonably procured this system should compete favorably with other means of establishing television networks.

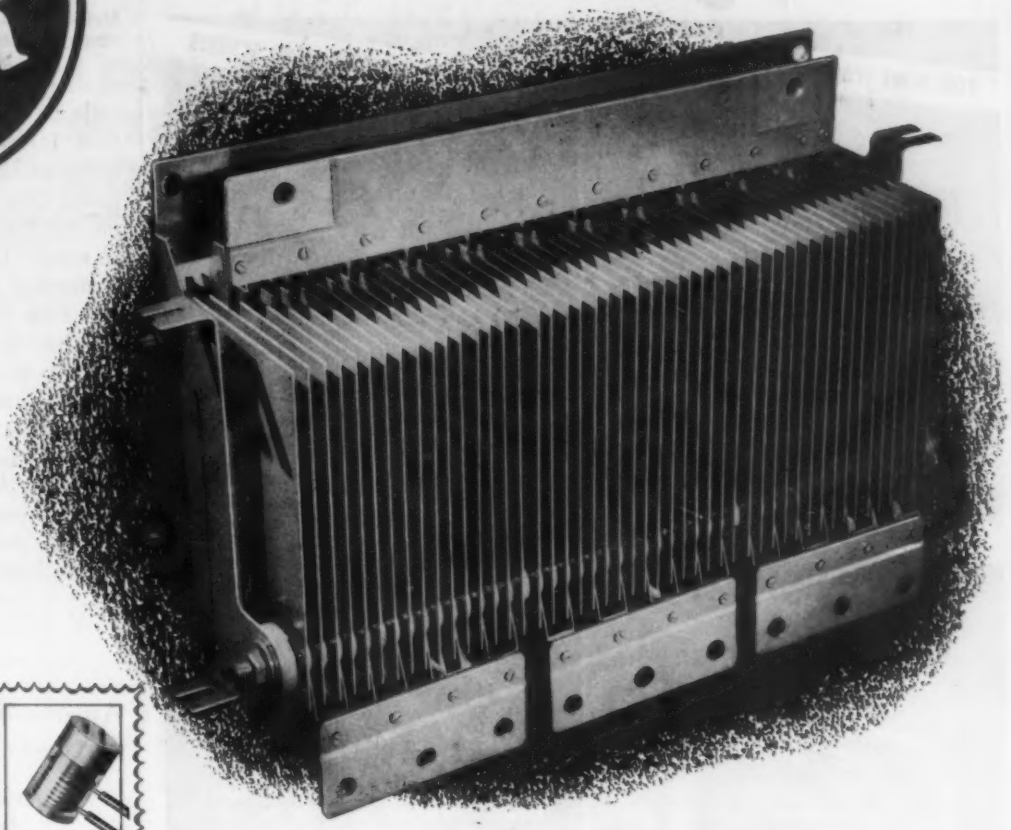
Rochester Fall Meeting

THE PROGRAM of the Rochester Fall Meeting of members of the RMA Engineering Department and the Institute of Radio Engineers at the Sheraton Hotel, Rochester, N. Y.,

(Continued on p 246)

The FIRST NAME in Selenium Rectifiers

FTR



. . . FROM MILLIWATTS TO KILOWATTS

YOUR ASSURANCE OF TIME-TESTED PERFORMANCE

THE THINGS YOU WANT most in a rectifier — lasting performance and dependability — can neither be seen nor accurately measured. But they *can* be *identified*. . . by the familiar "FTR" trademark. Why? Because Federal was the *first* manufacturer of Selenium Rectifiers in this country — because Federal has pioneered every major advance in their design and construction — and because, for over 9 years, Federal Selenium Rectifiers have continued to set the industry's standards for performance, economy, and long service life.

Whether your product uses DC by the milliampere — or by hundreds of amperes — there's a Federal Selenium Rectifier that's right for the job. For example: The "postage-stamp size" rectifier shown above delivers 5 milliamperes at 2,000 volts DC. . . while the large 48-plate three-phase stack furnishes up to 200 amperes at 30 volts DC, or 25 amperes at 240 volts DC. Both have one thing in common — the traditional Federal quality and dependability. Write today for information on the rectifier for *your* power-conversion requirements. Dept. F413.

Federal Telephone and Radio Corporation

KEEPING FEDERAL YEARS AHEAD... is IT&T's world-wide research and engineering organization, of which the Federal Telecommunication Laboratories, Nutley, N. J., is a unit.

SELENIUM and INTELIN DIVISION, 1000 Passaic Ave., East Newark, New Jersey

In Canada: Federal Electric Manufacturing Company, Ltd., Montreal, P. Q.
Export Distributors: International Standard Electric Corp. 67 Broad St., N. Y.

Need fastenings?

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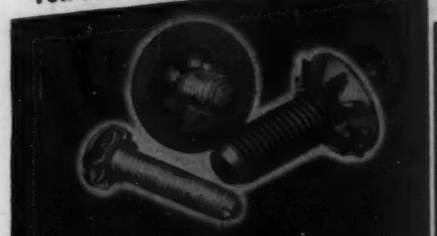
FOR SEMS WASHER SCREW ASSEMBLIES



Washer permanently fastened on, yet free to rotate. Easier, faster driving. No fumbled, lost or forgotten washers. Matching finish on both parts. Easier ordering and balanced inventories.

FOR PHILLIPS RECESSED HEAD SCREWS

Increase assembly speed up to 50%! Cut down injuries to workers with no burrs, no skids. Reduce production costs. Reduce rejects! Improve product appearance! Go modern with Phillips!

FOR CLUTCH-HEAD SCREWS

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FOR SPECIAL COLD-FORGED FASTENINGS

Scovill is expert in cold-forging unusual special fastenings, such as the one shown. Scovill designing ability, engineering skill, men and machines save money for customers. Consult Scovill!

Look at the fastenings you're now using—and see if they're the best for the job. Get better results—at less cost—with modern fastenings. If you use fastenings in *large quantities*, it will pay you to find out what Scovill can do for you. Fill out and mail the coupon below—*now!*

MAIL COUPON TODAY!

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QUALITY FASTENERS FOR QUANTITY CUSTOMERS

SCOVILL MANUFACTURING COMPANY
WATERVILLE SCREW PRODUCTS DIVISION E-11
WATERVILLE 48, CONN.

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NAME_____

COMPANY_____

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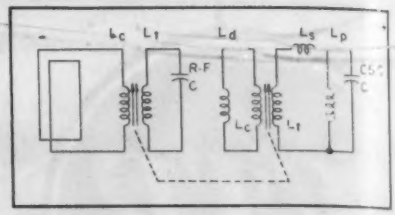
TUBES AT WORK
(continued from p 142)



Method of neutralizing effect of loop antenna reactance on tracking of permeability-tuned receiver

coils be identical in every position, that is, at every frequency. The effect of the coupled reactance is to upset this condition. Hence a simple solution suggests itself, namely, to couple into the oscillator section a dummy coil of the same inductance as that of the loop antenna. The reactance coupled into both sections is then the same at every frequency and mistracking does not result. A typical circuit is shown. Here L_1, L_1 represent identical coils and cores, L_c L_c identical primaries wound over them, and L_d the dummy coil simulating the effect of the loop L.

(1) ELECTRONICS, **19**, p 138, Sept. 1946.
(2) *Radio*, **30**, p 20, Nov. 1946.

Automatic Audio Phase Reverser

By ALVIN H. SMITH
Technical Supervisor
Radio Station KSJC
Sioux City, Iowa

IT IS a well known fact that the waveform of most speech and some music is not symmetrical. When such a nonsymmetrical signal modulates an a-m transmitter, it is possible for the modulation envelope to undergo excursions below the unmodulated level that are greater than the envelope excursions above this level. Such a condition is referred to as negative modulation. Most broadcast transmitters can accommodate positive modulation peaks in excess of 100 percent, but in no case can the negative modulation peaks exceed 100 percent, or serious distortion and interference to other radio services will result. Moreover, most detector distortion in modern broadcast receivers occurs on the negative portion of the detection curve. Thus, if a nonsymmetrical modulating signal can be made to produce more positive than

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MUST HAVE

LOW NOISE LEVEL
MINIMUM VIBRATION
CONSTANT SPEED

For Prompt Service
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EASTERN AIR DEVICES
SYNCHRONOUS SOUND RECORDER MOTORS

Give Smooth, Flawless Performance
ON ANY TYPE OF DISC, WIRE, TAPE or FILM RECORDER

1. NO NOISE – HYSTERESIS TYPE
2. NO VIBRATION
3. HUNT and "WOW" ELIMINATED

These Motors Now in Production

TYPE	H.P.	SPEED
LH731NCJ	1/50	1800 R.P.M.
LH73QCJ	1/100	1800 R.P.M.

WRITE FOR SAMPLES

Similar Motors are Available For:
CAMERAS • PROJECTORS • FACSIMILE

EASTERN AIR DEVICES, INC.
585 DEAN STREET • BROOKLYN 17, N. Y.

MODEL P-52HF

TRU SONIC

Separate 2-Way Speaker System

Required

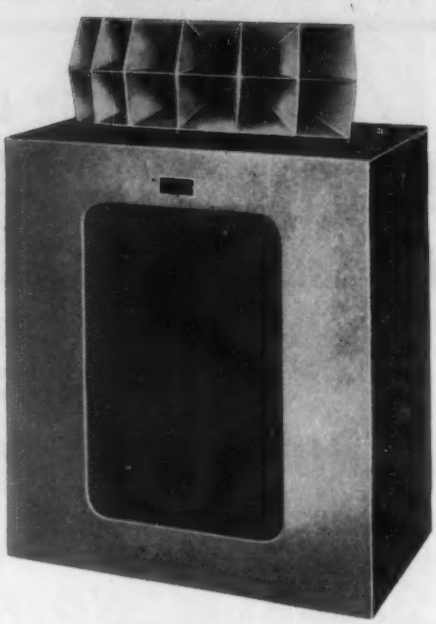
FOR FM

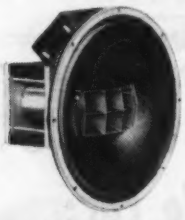
BROADCAST MONITORING

Illustrated on the right is the complete fulfillment of the broadcasters requirements for adequate monitoring of the extended range FM signal. Features of the P-52HF Tru-Sonic separate 2-way speaker system include low 800 cycle crossover to relieve the low frequency driver cone of high frequencies—6 cubic foot phase-inverted reflex cabinet for adequate bass support—120° x 40° high frequency dispersing horns—over 6 pounds of Alnico 5 magnet for high flux density in the gaps—efficiency over 50%—high frequency attenuation control to balance room acoustics—least inter-modulation, and fewest transients of any comparable speaker.

Shown in the Model 52U utility cabinet. Available also in exquisite furniture of period design in either bleached blond or mahogany, with components totally enclosed.

Model P-52HF with 2x6 horn, as shown, *$345.00 list.* With 2x5 horn, *$332.50 list.* With 2x4 horn, *$320.00 list.*



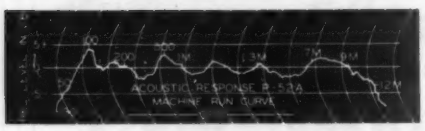


P-52A Coaxial 2-Way System

For Home Reception

The Model P-52A Coaxial 2-way speaker system embodies the same fine engineering and construction exemplified in the P-52HF Separate 2-way system shown above, *plus* the added feature of space saving design. 1200 cycle crossover—80° x 40° dispersion through 8 cellular horns—heavy, 6 pound Alnico 5 magnet for high flux density—16 ohm, 20 watt input—15" cone diameter. Price *$205.00 list.*

Normal trade discounts prevail. Write for 16 page bulletin describing Tru-Sonic speaker systems.



STEPHENS

MANUFACTURING COMPANY

10416 National Blvd. Los Angeles 34, Calif.

Speaker Systems for TRU SONIC *Theatre and Home*

negative modulation peaks, the coverage of a radio station may be increased, and, at the same time, overall distortion can be reduced.

The purpose of this a-f phase reverser is to adjust automatically the polarity of the audio input signal to the transmitter to produce the desired modulation polarity. This device is particularly useful when the modulating signal is of local studio origin; after an audio signal has passed through a number of repeater amplifiers, as in the case of a network program, phase and amplitude distortion cause the lack of waveform symmetry to be less pronounced.

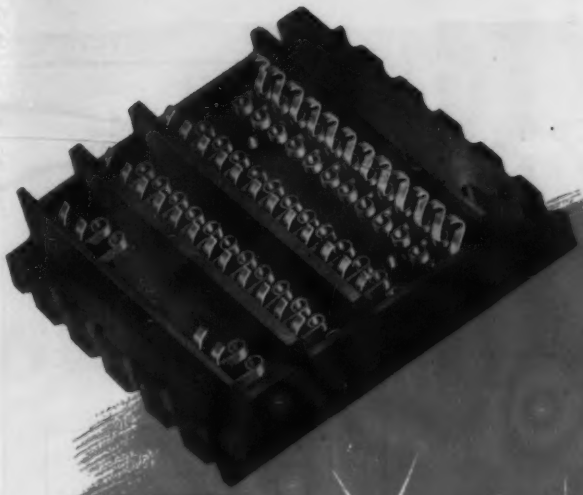
Circuit Operation

The circuit of the automatic phase reverser is shown schematically in the accompanying illustration. Basically, the device consists of a two-stage bridging audio amplifier using 6C5 tubes, a balanced rectifier, consisting of a 6H6 with one cathode grounded, and an R-C delay network, the output of which is connected to the control grid of a 2050 thyratron. The firing of this thyratron actuates a polarity-switching relay.

A dpdt sense switch is connected in the input of the phase reverser unit. This switch is used to preset the phase reverser so that on modulation peaks, the transmitter will be modulated more positively than negatively. Once the proper switch position is selected, no further adjustment is required and the operation of the device is entirely automatic.

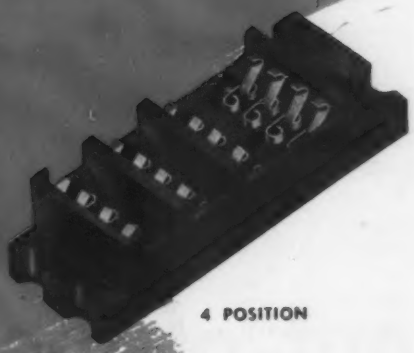
Conventional audio amplifiers are used and are designed to produce minimum distortion, since the waveform of the incoming audio signal must be preserved as nearly as possible. The 6H6 balanced rectifier operates in such a manner that for low audio input voltages, the potentials across the two halves of the output load are approximately equal. Under this condition, the net voltage across the R-C delay network is nearly zero.

On input voltage peaks, the rectification efficiency increases, and the diode having the higher input voltage peak develops the larger voltage across its load. As a result, a voltage is impressed across the input



12 POSITION

6 POSITION



4 POSITION

4 6 12 PLASTICS PARTS* THAT COUNT!

These plastics terminal blocks are component elements of "4-6-12" position transfer supports . . . *vital parts* in the complicated maze of electronic devices which make up the modern business machine . . . *parts that count* in speeding-up present-day accurate accounting practices and efficient business methods.

Compactness in assembly is always the first requirement in this type of unit. Only a carefully engineered transfer molding procedure could meet the rigid specifications of the application and accomplish so much while occupying so little space . . . *forty* separate terminal contacts in an area less than two inches square for the 12 position shown above (other parts proportionately less).

Manufacturers in all fields have learned to *count* on Consolidated for the production of important, functional plastics parts. Material development, precision mold-construction and final processing at our "under-one-roof" plant add up to and dovetail into a complete and eminently satisfactory *custom* molding service. We will be glad to bring the advantages of our full facilities and plastics know-how to your next product application. Inquiries invited!

*** Parts Shown thru Courtesy of International Business Machines Corp.**

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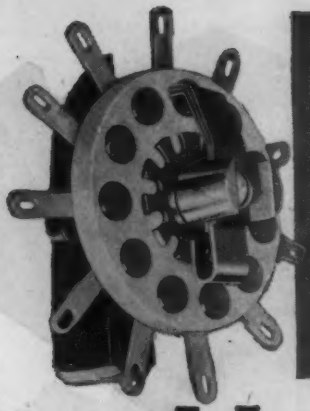
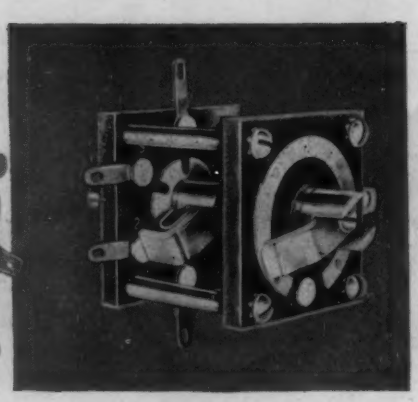
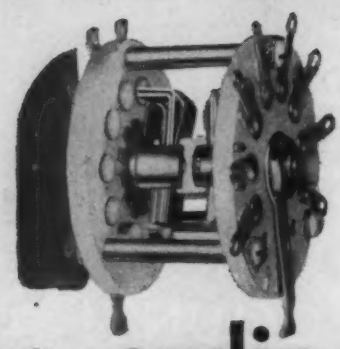


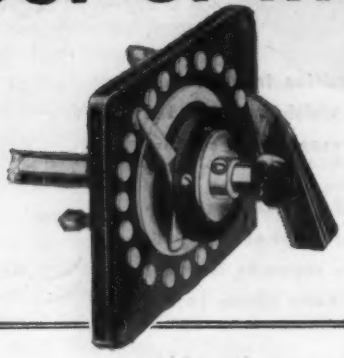


Shallcross

for



out-of-the-ordinary



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1.5 to 200 KV

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1 to 7 dial types, 0.1 to 11, 111, 110 ohms

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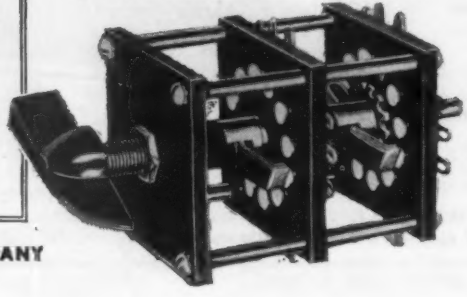

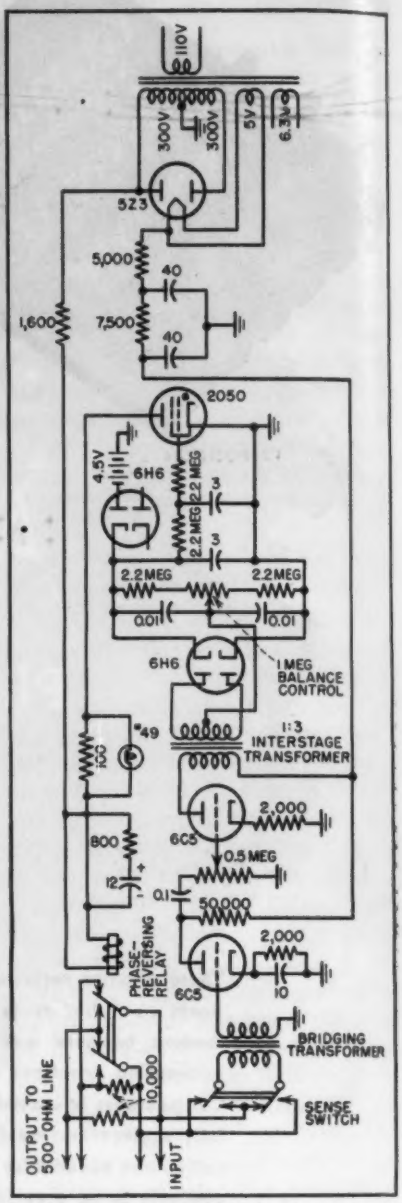

Automatic phase reversal of an audio signal is done by this circuit

of the delay network having a polarity that is determined by the predominance of negative or positive peaks at the rectifier input.

Plate voltage for the 2050 thyratron is supplied by one-half of the high-voltage winding of the power-supply transformer through the winding of the polarity-switching relay. The thyratron normally conducts on every positive half-cycle of its plate voltage. Whenever the net voltage from the balanced rectifier is such that the grid voltage of the thyratron is approximately 3 volts negative, the thyratron ceases to fire and the relay switches to its unenergized position, reversing the polarity of the

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Advantages to the ultimate producers of these commodities are: They get their parts *precision-made*, on-schedule, at lowest possible cost. They get their parts without investment in new machinery, new buildings, new personnel.

Paul and Beekman, Inc. *has* the plant, the machines, the skilled men and the organized planning. We make all types of pressed metal parts and products from steel, bronze, copper, brass or aluminum. If desired, we design and make the dies. If specifications call for welding, assembling or electroplating, so much the better . . . we do that, too.

Perhaps that kind of start-to-finish service can help you remain competitive, in the face of rising costs. A letter to us, stating your needs, will put our engineers to work on your problem, *immediately*.

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subsidiary of Portable Products Corporation

audio signal delivered to the transmitter.

A two-section R-C delay network is connected to the grid of the thyratron. This delay network aids in preventing chattering of the relay and delays switching until several peaks of the same polarity have occurred. Two 10,000-ohm resistors across the relay contacts act to reduce key clicks in switching; relay contacts should be set as close as possible for the same reason. The combination of the 12-μf capacitor in series with the 800-ohm resistor also acts to prevent relay chattering.

Control of Switching Time

A 6H6 clipper tube prevents the delay-network capacitors from charging negatively to such a degree that the switching action of the thyratron can not follow rapidly the peak polarity changes of the audio signal. The grid circuit of the thyratron performs this function for positive capacitor charges. Adjustment of the audio input to the balanced rectifier also affects the time required for switching.

The value of the resistor in series with the plate of the 2050 depends upon the characteristics of the particular relay used. This resistor should have as high a value as will give good switching action. A desired switching delay can be obtained by changing the values of the circuit constants in the R-C delay network. The only limitation is that the resistance in series with the 2050 grid must be at least 300,000 ohms.

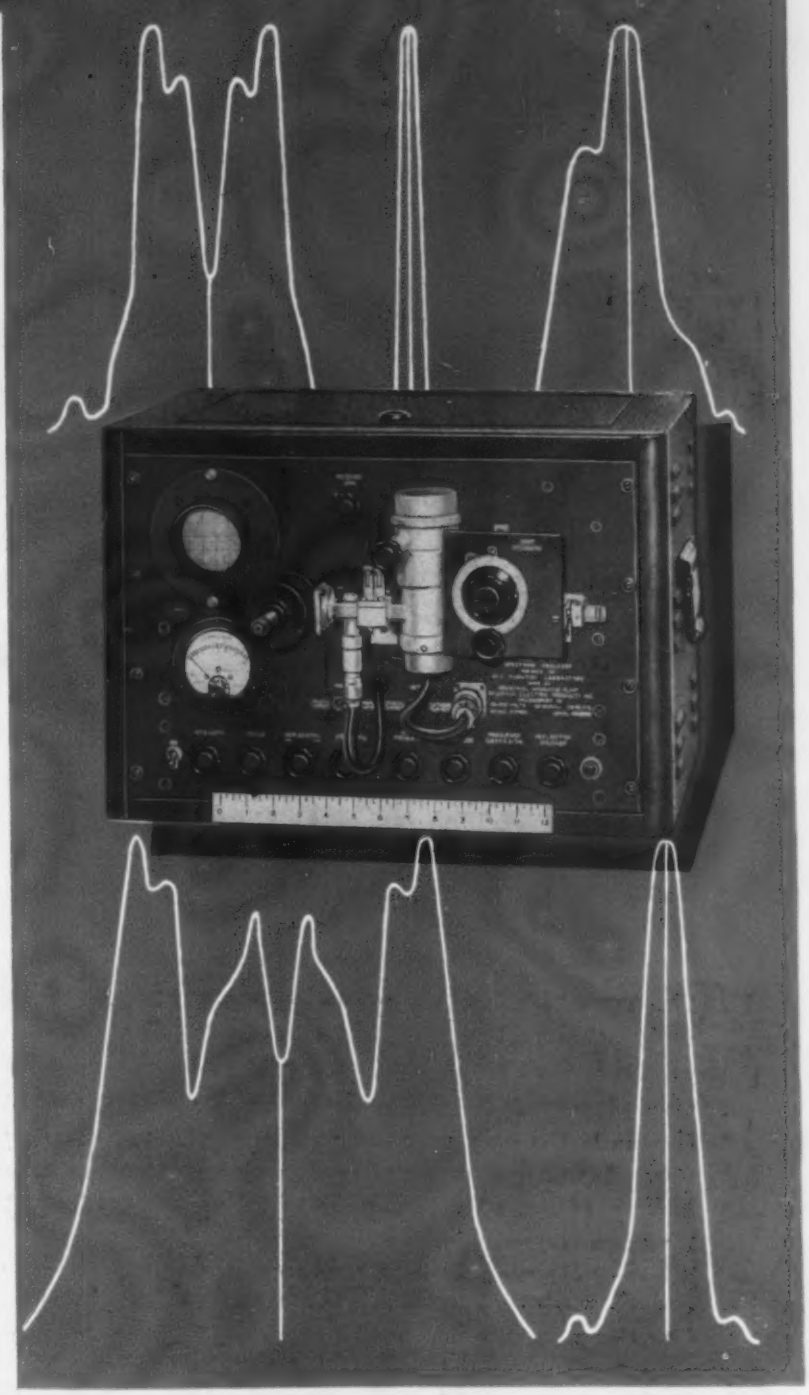
The automatic phase reverser neither adds to the distortion nor increases the noise level of the audio circuit with which it is connected. This condition results from the fact that the audio circuit has only a dpdt relay added to it. This device has proved to be very useful in several months of service at KSJC.

Dust Precipitators for Air Conditioning

NO LONGER must spectators at Madison Square Garden see sporting events and spectacles through a discomforting haze of tobacco smoke and dust. In conjunction with the air conditioning system recently in-

Studying the output of pulsed oscillators?

ANALYZE THEIR SPECTRA VISUALLY WITH THIS COMPACT INSTRUMENT!



THE SYLVANIA SPECTRUM ANALYZER

provides a convenient means of studying the energy spectrum of microwave generators operating as pulsed oscillators or modulated CW oscillators. The output of magnetron, klystron, rocket and similar UHF and SHF tubes can be readily investigated.

Essentially, the Sylvania Spectrum Analyzer consists of a sharply tuned superheterodyne receiver with a cathode ray oscilloscope indicator. The instrument incorporates a sawtooth generator, which performs the two functions of frequency-modulating the local oscillator and of providing the horizontal sweep for the oscilloscope. Thus automatic synchronization is assured at all times.

An input probe is provided for insertion into cavities or wave-guides.

The energy emitted by the oscillator at various frequencies is displayed on the cathode ray tube as a pattern of vertical lines. The envelope of the pattern represents the spectral distribution.

The Spectrum Analyzer illustrated—the TSX-4SE—is designed for the 9,300 Mc region. A second model—the TSS-4SE—is available for the 3,000 Mc region, and a third model—the TSK-2SE—is available for the 24,000 Mc region.

TYPICAL APPLICATIONS OF THE SPECTRUM ANALYZER

Some of the possible uses include:

Viewing the output of a radar system, to make sure that the output energy is not being wasted by being distributed over a wider frequency band than the radar receiver can accommodate.

Determining the frequency of a pulsed oscillator.

Adjusting the local oscillator frequency of a radar receiver to space it properly with respect to transmitter frequency.

Checking of pulling or shifting in frequency of the pulsed oscillator of a radar transmitter, by observing the spectrum while the antenna is in motion.

Measurement of standing wave ratios by using the Spectrum Analyzer in conjunction with a slotted section.

WRITE FOR DETAILED SPECIFICATIONS

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Electronics Division . . . 500 Fifth Avenue, New York 18, N. Y.

MAKERS OF ELECTRONIC DEVICES: RADIO TUBES; CATHODE RAY TUBES; FLUORESCENT LAMPS, FIXTURES, WIRING DEVICES; ELECTRIC LIGHT BULBS

Low NEEDLE TALK CARTRIDGE INVADES Low PRICE FIELD

Exclusive New Type "LT" Cartridge Introduced by Astatic

Where high sensitivity, excellent reproduction, low needle noise or needle talk, and low needle pressure are required . . . and cost economy is an important factor . . . Astatic earnestly recommends this new Model "LT" Crystal Cartridge.

In the reproduction of high frequencies, this cartridge is noticeably free from disagreeable and annoying surface noise or needle talk . . . thereby providing increased tonal clarity and beauty for greater phonograph enjoyment.

The Type "T" Needle employed in the "LT" Cartridge is replaceable and is furnished with an "Electro Formed" precious metal playing tip. Matched to the Cartridge, to give permanent Needle performance, this new Type "T" Needle is the only one that can be used, thus assuring constancy of the quality of reproduction regardless of the number of times the Needle may be replaced. Special literature is available.

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Astatic Crystal Devices Manufactured under Brush Development Co. patents

FIG. 1—Airborne particles receive a positive charge as they pass through this ionizer unit

stalled in the Garden, one of the largest indoor installations in the world of electrostatic precipitators has been made.

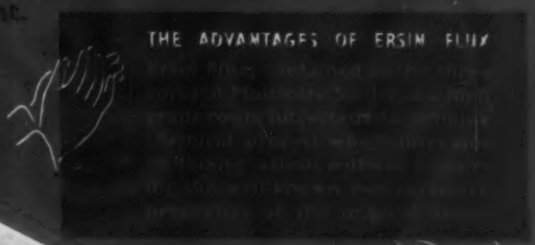
The air conditioning system in the Garden comprises eight individual systems, each handling 67,500 cu ft per min, or a total of 540,000 cu ft per min. The precipitator installation also comprises eight units, each having thirty cells and ionizers. The cross-section area of each bank of precipitators is 13 by 15 feet. These are installed in the duct work between the dehumidifiers and the fan in such a man-

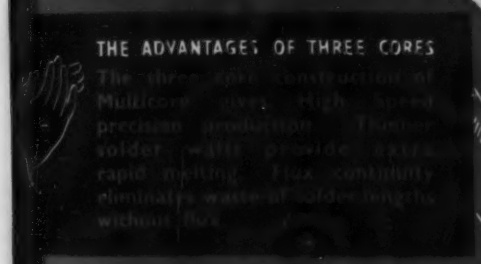
FIG. 2—Positively charged particles are deposited on these negative collector plates

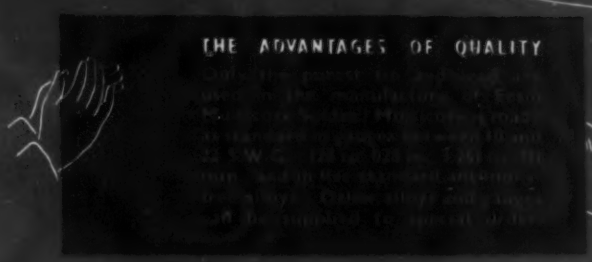
The Finest Cored Solder in the World

ENCORE!

Ersin Multicore Solder was the first solder in the world to be made with THREE cores—and it is the only solder in the world made with extra-active non-corrosive ERSIN FLUX. No other solder offers you the same advantages of speed, efficiency, and economy per joint.







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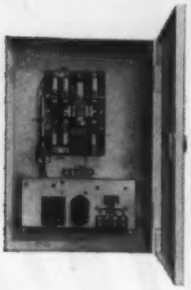
Fully Housed Electric Plants 10KW-35KW

Storms, floods or mechanical breakdowns may interrupt mainline power, but radio station WING of Dayton, Ohio, *stays on the air.* Its dependable Onan Standby Electric Plant is always ready to take over the power load in event of power failure, supplying electricity for broadcasting and other essential uses.

WING's 35,000-watt Onan plant, Model 35JT is built for full-capacity service, powered by a heavy-duty, six-cylinder water-cooled gasoline engine. This complete unit is equipped with built-in engine-instrument and A.C. meter panel. Streamlined, compact steel housing protects plant and accessories. Low in first cost, the Onan plant operates economically and requires a minimum of maintenance during idle periods.



PLANT STARTS AUTOMATICALLY WHEN POWER FAILS

Within seconds after a break in mainline power, the Onan Line Transfer Control starts the standby plant and switches its power onto the electrical system. When service is restored, the control automatically stops the plant. The built-in rectifier, a special feature of Onan controls, keeps batteries charged at all times.

ONAN ELECTRIC PLANTS are available in many sizes and models—A.C.: 350 to 35,000 Watts in all standard voltages and frequencies. D.C.: 600 to 15,000 Watts, 115 and 230 Volts. Battery Chargers: 500 to 6,000 Watts, 6, 12, 32 and 115 Volts.

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ONAN STANDBY POWER

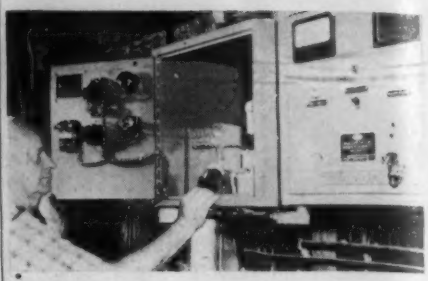


FIG. 3—High-voltage power supply for the precipitator units

ner that all of the air supplied to the Garden passes through the electronic filters.

In the electrostatic precipitators installed by Raytheon Manufacturing Co., all airborne particles are taken through an electrostatic field. These particles become positively charged and are precipitated onto negative collector plates. In this manner, 85 percent of all particles as small as 4×10^{-6} inch, a size that includes smoke particles, are effectively removed.

Figure 1 shows the ionizer section of one precipitator unit. A collector unit is shown in Fig. 2, and the high-voltage power supply in Fig. 3.

Five smaller electrostatic precipitator installations are now being placed in operation in the air conditioning system of the New York Stock Exchange. Two of them have been in operation since last November. These installations handle 54,000, 27,000, 22,500, 18,000 and 15,000 cu ft per min; all are equipped with precipitators primarily to remove coal dust and other types of dust usually prevalent in the downtown area of New York.

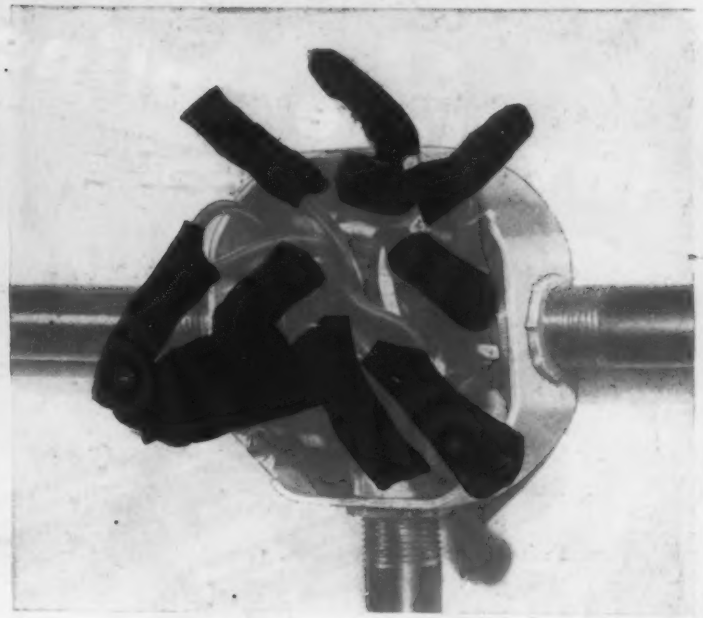
Spectrophotometer for FBI

BY USING a recording spectrophotometer, the Federal Bureau of Investigation Laboratory in Washington, D. C. can trace cars used by hit-and-run drivers.

According to D. J. Parsons of the Laboratory, in a General Electric Science Forum talk, the clue most helpful to the investigators is information as to the kind of car involved.

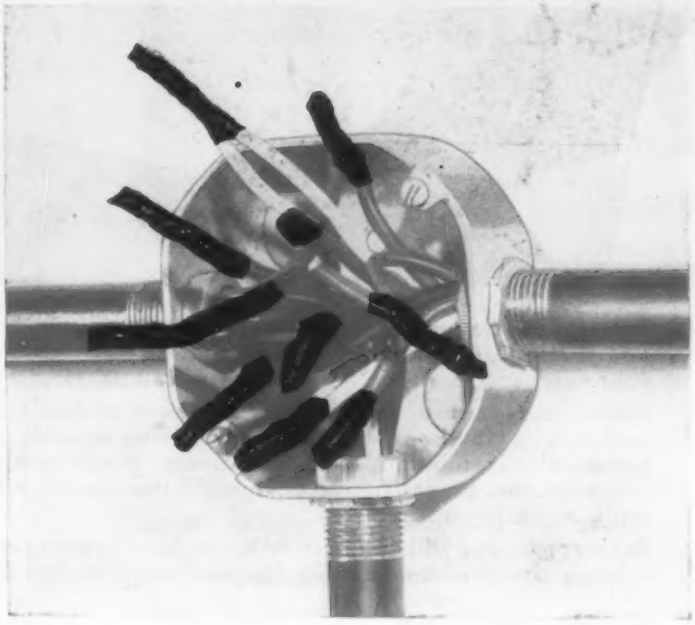
Frequently the clothing of the victim struck down on the highway will be examined, and minute specks or smears of paint from the auto-

Do your junction boxes look like *THIS*..



Junction box overstuffed with wire splices wrapped with rubber tape and an outside wrap of friction tape. When these bulky splices are jammed in you really have an overstuffed junction box.

or like *THIS?*



This junction box has the same number of splices, but they are wrapped with No. 33 "SCOTCH" Electrical Tape with Vinyl Plastic Backing. The thinness of the tape makes the difference in the bulk of the wrapped splices.

If your junction boxes are overstuffed with splices wrapped with rubber tape and friction tape switch to

No. 33

REG. U. S. PAT. OFF.

SCOTCH BRAND *Electrical* TAPE

WITH VINYL PLASTIC BACKING

LISTED UNDER REEXAMINATION SERVICE — UL — UNDERWRITERS' LABORATORIES, INC.

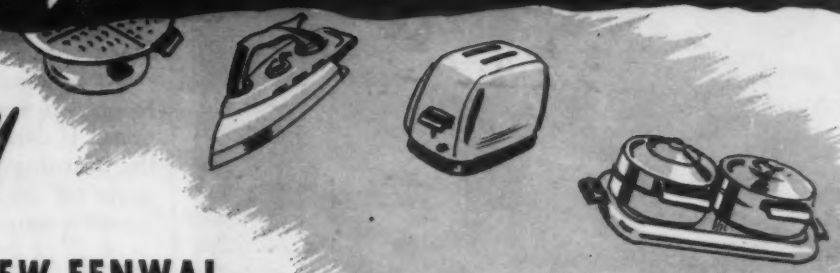
For Superior Dielectric and Mechanical Protection

With an overall thickness of .007" No. 33 "SCOTCH" Electrical Tape with Vinyl Plastic Backing has a dielectric strength of 8000 volts. OTHER ADVANTAGES—high stretch, flexibility and resistance to flame, water, oils, acid, alkalis.

Write for a free sample to try in your own work.

Made in U.S.A. by MINNESOTA MINING & MFG. CO. St. Paul 6, Minn.
and 3M COMPANY

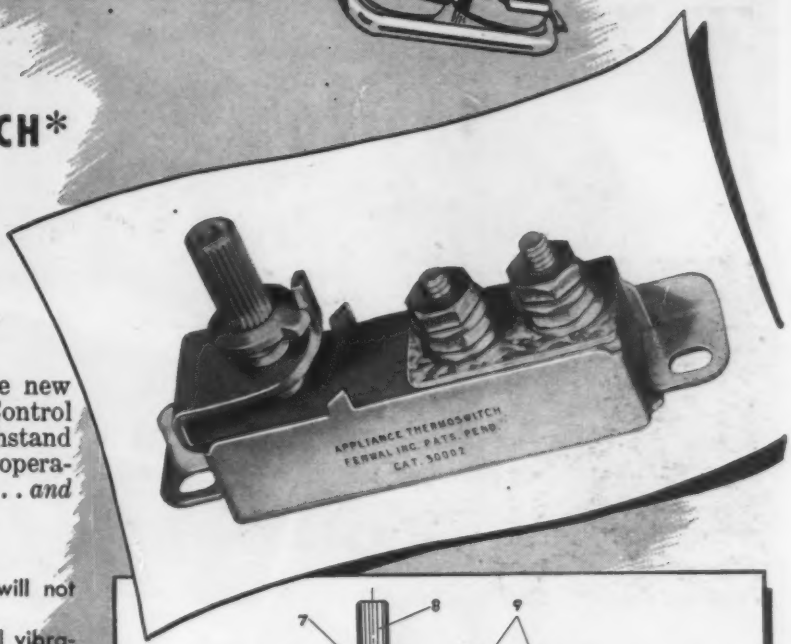
If your product uses HEAT



Specify THE NEW FENWAL APPLIANCE THERMOSWITCH* CONTROL

Safe • Accurate • Long-Lasting Temperature Control For All Types of Electrical Appliances

The unique and rugged design of the new Fenwal Appliance THERMOSWITCH Control provides a heat control unit that will withstand shock, vibration, tampering and other operational hazards that lower product life . . . *and influence buying attitudes.*



Note these outstanding features:

- Torque applied to terminal binding posts will not shift contact support members.
- Adjusting screw will not drift under normal vibration.
- The mounting bracket provides for side or bottom mounting, or a cross-mounting bracket is available for special applications.
- One-piece, welded case and cover assures rugged, tamper-proof unit . . . stable temperature settings.

TWO DISTINCTLY DIFFERENT MODELS FOR HIGH AND LOW TEMPERATURE RANGES

The Appliance THERMOSWITCH Control is available in models especially designed for both high and low temperature ranges. The high temperature model provides control over the wide range of 175°F.–600°F. The low temperature model provides extremely critical control for low temperature applications throughout its range of 50°F.–250°F. Each model assures the highest degree of efficiency and dependability; both incorporate the outstanding Fenwal characteristics.

SPECIFICATIONS

Overall case dimension: ½" high x 5/8" wide 2⅛" long.
Maximum Load Rating: 1200 watts on 110 volt 60 cycles.
TEMPERATURE RANGE:
50° F. to 250° F. (Series 30003)
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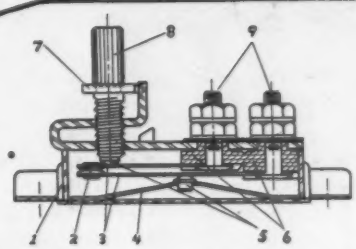

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mobile are found and removed. The ability of the questioned material to absorb or reflect the various colors and hues of the visible spectrum is determined. The instrument most useful in this procedure is the recording spectrophotometer.

The results of the analysis are searched in the National Automotive Paint File which contains the standard samples of paints and finishes used by the various automobile manufacturers and the make of the car is determined.

Instruments Speed Oil Refining

THE MOST advanced techniques of electronics, pneumatics, and pyrometry are being incorporated in modern oil refineries to obtain practical operation of the huge refining units being built for continuous, mass processing of tens to hundreds of thousands of barrels of crude oil daily. Instrumentation is also achieving the lower costs that go with mass production in refineries.

An instrument nerve system measures and automatically regulates the pulses of speed, volume, pressure and heat in every refinery pipe and tower and enables the handling of massive forces and volumes, which man could not otherwise control with the necessary precision.

Large control rooms now built into each major unit are connected to as many as 500 instruments and control points throughout the unit as in the case of the Gulf Oil Corp. new fluid catalytic cracking installation at Philadelphia.

Varying reactions of the process are conveyed from the outside instruments into the control house where recording and adjustment of the variations is effected under the eye of the chief operator, either automatically by the instruments, by manual instrument control, or by communication with workers manning the installation. Pneumatic lines both bring in the instrument responses and activate process adjustments and form an elaborate air pressure transmission system developed to eliminate hazard of fire or explosion from electric wiring.

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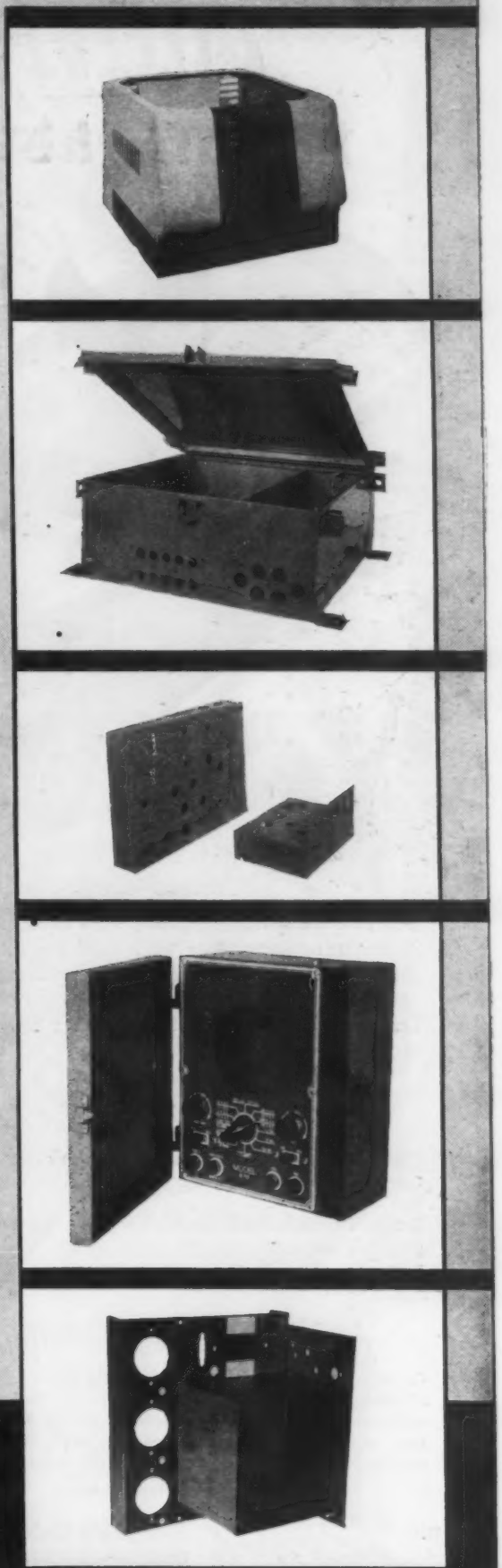

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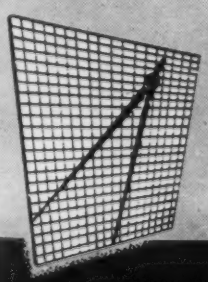

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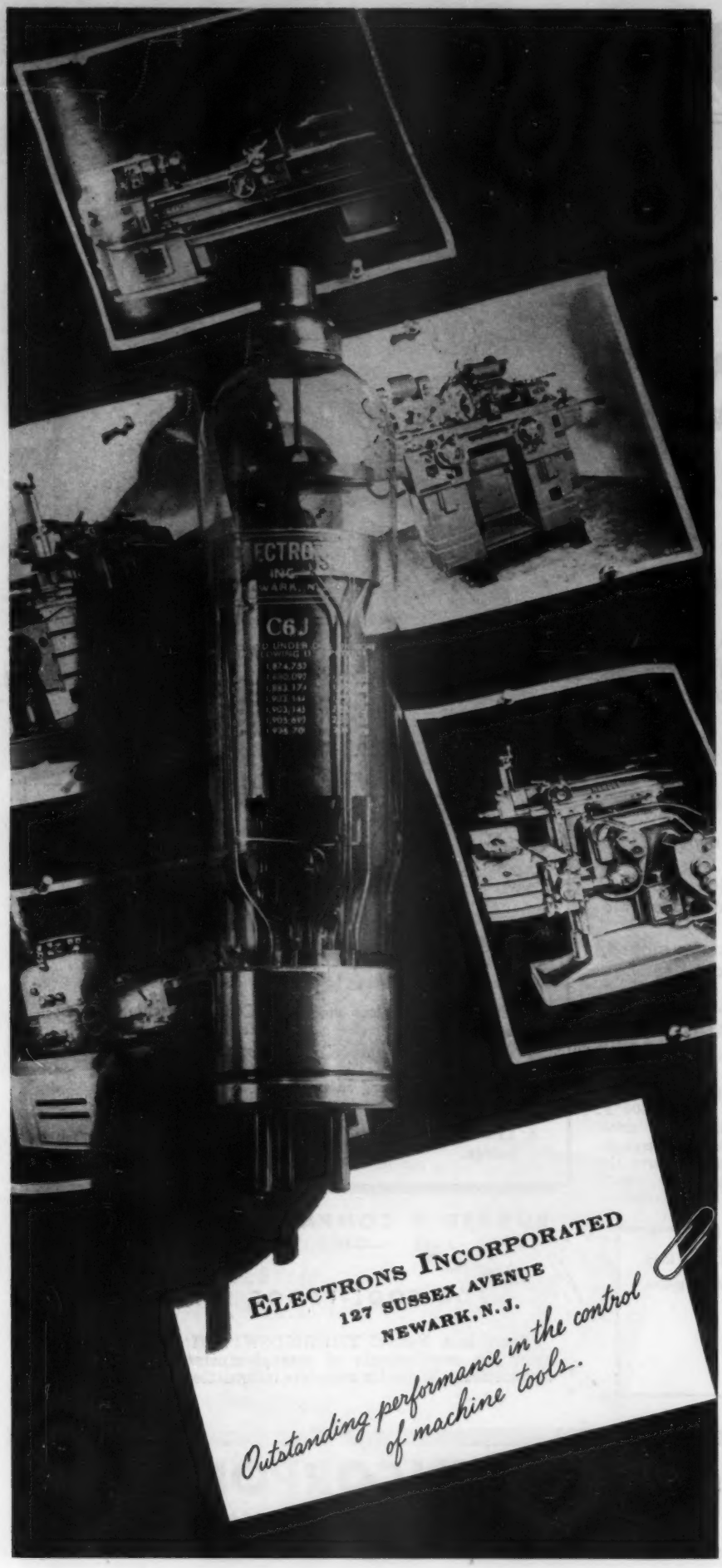
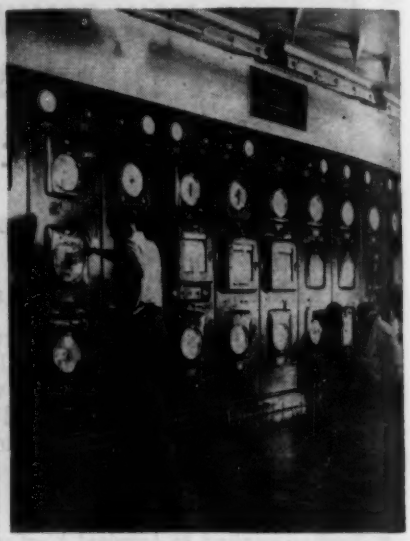


are used to record temperatures where high speed recording is essential. Absolute safety is provided by automatic pre-alarms, alarms, and shut-offs that signal the operators when any part of the complicated processing system is failing to operate according to set conditions. If corrections are not made, the warning device automatically shuts off the affected installations before a danger point is reached.



Scores of electronic, pyrometric, and pneumatic instruments are mounted on the four walls of this air-pressurized control room to direct 500 control points in the giant new catalytic refining unit built by Gulf at Philadelphia

In the early days of the oil refining industry, instruments had to be read and the process adjusted at points located about the stills. This made impossible the coordinated picture needed for large operations and the stills sometimes could not be kept operating up to 100 hours. Today, giant, precision-directed units can run from six months to as long as a year in some cases without interruption, turning out a greater volume of gasolines and lubricants than ever before.

Devices which have effected the change from small batch operation to mass production include level controllers to chart and manipulate the level of fluid in towers and stills; flow, temperature, and pressure indicators, recorders and controllers; interconnected controls where valves are operated by different instruments in response to varying conditions; and special scanning graphic pyrometers, which

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Sound trucks with magnetic wire recorder-reproducers mean *better* announcements with *less* personnel! Here's a field that will net some aggressive engineer a neat piece of the profits in magnetic recording. Why don't you investigate? Look to the leader—Brush—for the finest in magnetic wire recording components!

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show a pattern of temperature at a glance.

Technical Data on Electronic Micrometer

CIRCUIT diagram and construction details of the electronic micrometer first described in this department (ELECTRONICS, July, 1947) have now been made available by the National Bureau of Standards. This device utilizes the variation in mutual inductance between two coils in a pickup assembly when the latter is displaced from a fixed metallic surface, to obtain a linear thickness-measuring characteristic.

Such a micrometer, designed to measure insulation thickness, is shown in Fig. 1. The instrument has two full-scale ranges: 0 to 0.005 inch, and 0 to 0.05 inch. Accuracy is better than 0.00005 inch on the low range and 0.0005 inch on the high scale. With suitable meter multiplier resistances, displacements in the order of 10^{-5} inch have been measured, although this is by no means the limit of sensitivity of this method of measurement.

Probe Coil Assembly

Experimental investigation was made of the effect of probe coil geometry on the linearity of the displacement characteristic. For a fixed primary and movable secondary coil having the same diameter, it was found that the mutual inductance increased linearly as displacement values changed from zero to

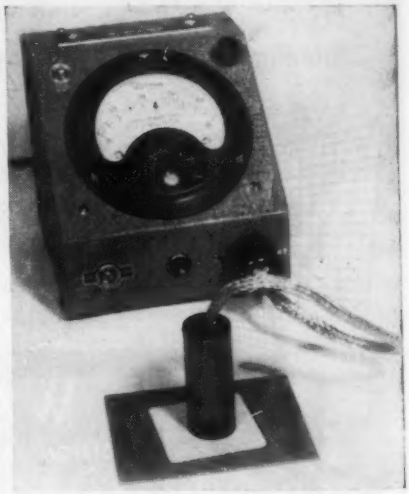

FIG. 1—Electronic micrometer measures change in coupling between probe coils caused by displacement of probe from metallic reference surface

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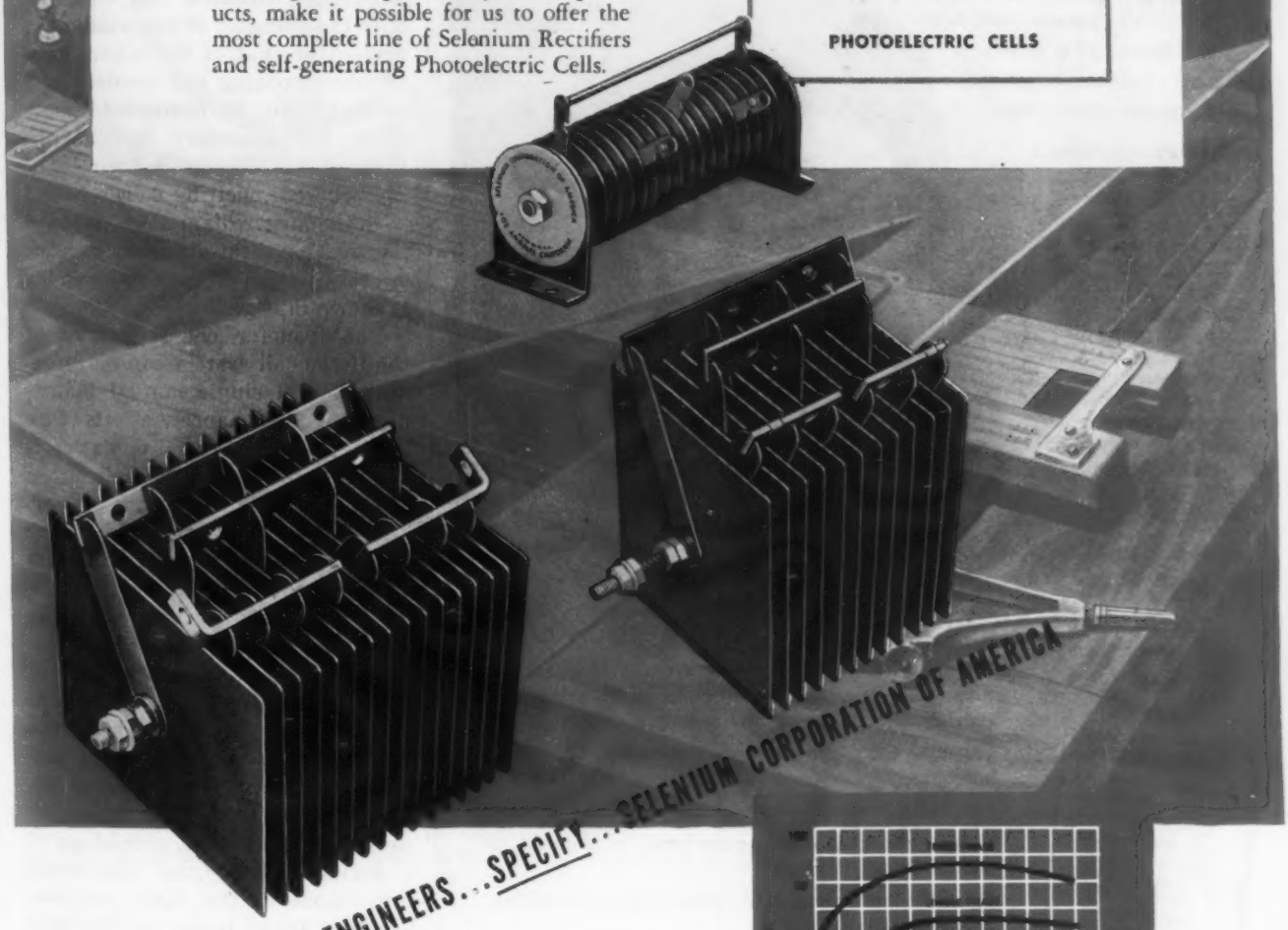

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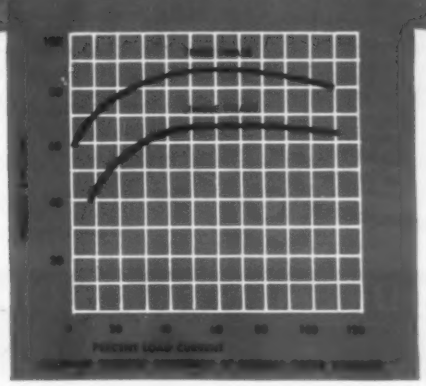

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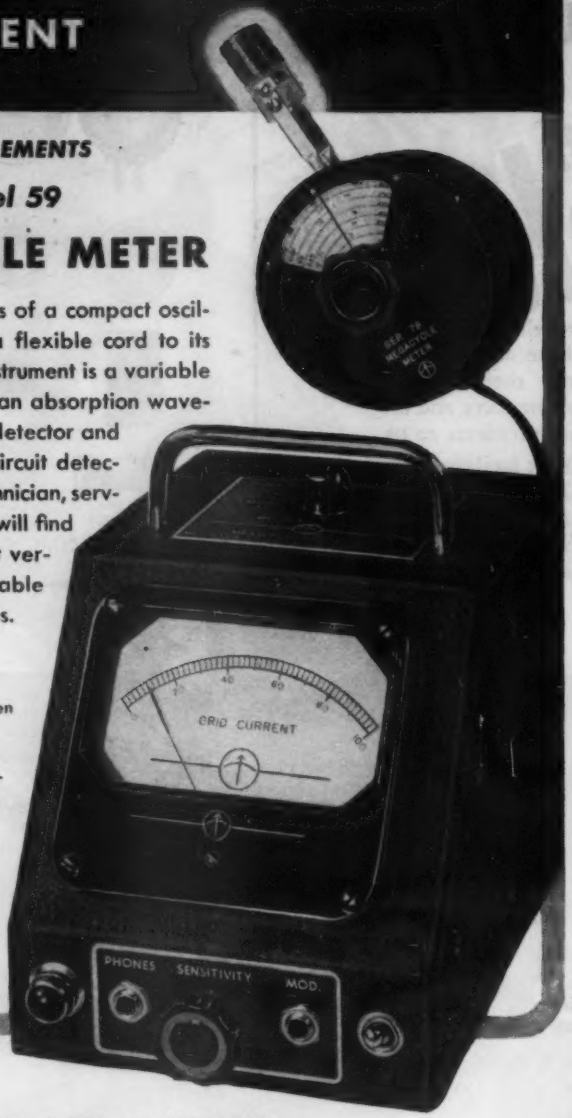
The Model 59 consists of a compact oscillator connected by a flexible cord to its power supply. The instrument is a variable frequency oscillator, an absorption wavemeter, an oscillating detector and a tuned absorption circuit detector. The engineer, technician, service man or amateur will find the Model 59 a most versatile instrument suitable for many applications.

SPECIFICATIONS:
FREQUENCY:
2.2 Mc. to 400 Mc.; seven plug-in coils.
MODULATION:
CW or 120 cycles; or external.
DIMENSIONS:
Power Unit, 5⅛" wide; 6⅛" high; 7½" deep. Oscillator Unit, 3¾" diameter; 2" deep.
POWER SUPPLY:
110-120 volts, 50-60 cycles; 20 watts.



MODEL 59 APPLICATIONS:

- For the determination of the resonant frequency of tuned circuits, antennas, transmission lines, by-pass condensers, chokes or any resonant circuit.
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- For preliminary tracking and alignment of receivers.
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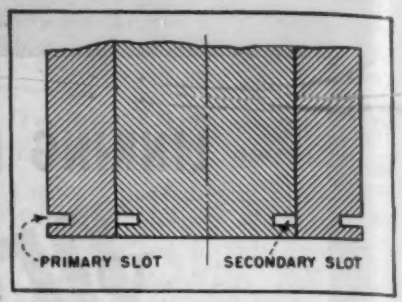

FIG. 2—Cross section of probe coil form

about 5 percent of the coil diameter.

The most advantageous mechanical design for the probe coil assembly necessitated the use of fixed windings on a single form. With this restriction on mechanical design, it was found that the optimum displacement-measuring characteristic was obtained by making the windings concentric and coplanar, with the diameter of one winding 70 percent of that of the other. The primary exciting coil consists of 8 turns of No. 26 enamelled copper wire; the secondary coil has 55 turns of No. 38 enamelled wire. The high-current exciting coil is wound with the larger diameter because of its greater heat-dissipating area. A cross section of the coil assembly is shown in Fig. 2.

The transfer characteristics of the probe coil system can be represented by a single mutual inductance if resonance effects are avoided. Non-resonant operation is desirable for precision applications because of its independence of operating frequency and lower coil losses. Operation at frequencies below resonance may not be satisfactory because harmonics of the exciting frequency may be accentuated, possibly causing distortion of the linear relation of output voltage with displacement. To keep the resonant frequency as high as possible, the rectifier is mounted directly on the probe coil form. A simple low-pass filter, consisting of a series resistor and the shunt capacitance of the diode rectifier, has been found to reduce the resonance rise to negligible proportions.

Oscillator and Control Circuits

The primary winding of the probe assembly is driven by a 3-mc oscillator shown schematically in Fig. 3. A feedback network controls the oscillator screen voltage so

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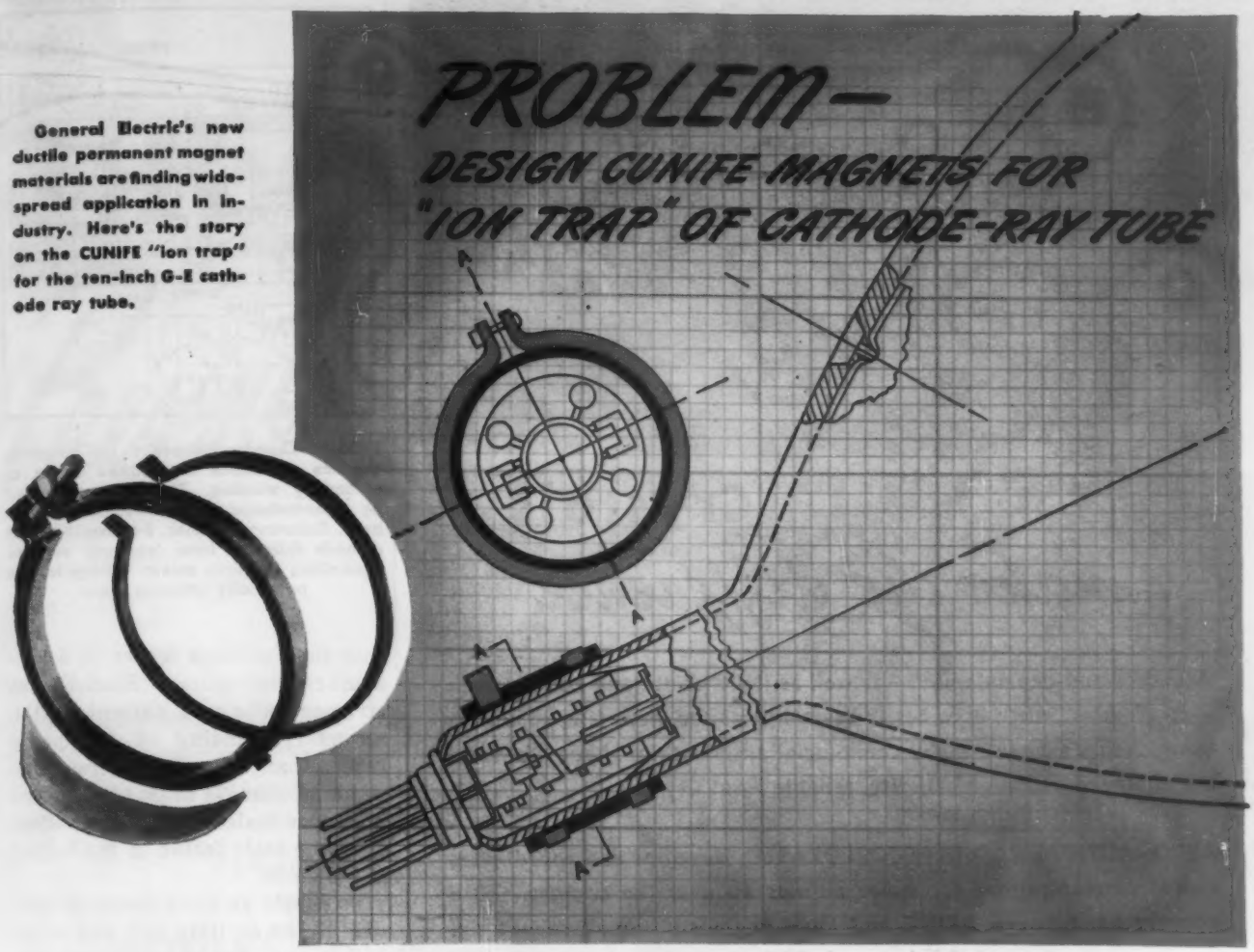
General Electric's new ductile permanent magnet materials are finding widespread application in industry. Here's the story on the CUNIFE "ion trap" for the ten-inch G-E cathode ray tube.



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Two ring-shaped G-E permanent magnets made of ductile CUNIFE are now used on cathode-ray tubes to help eliminate the troublesome ion spot on the direct view television screen. When mounted in the correct position on the tube neck surrounding the electron gun, these CUNIFE rings supply the magnetic field which deflects the electrons out of the ion-electron stream. The deflected electrons are thus rapidly returned to their original course while the massive ions are "trapped" and do not strike the tube screen.

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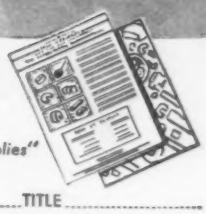

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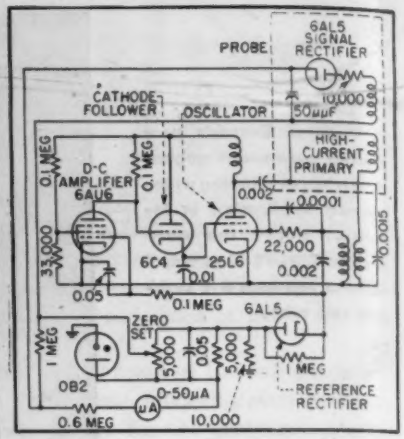

FIG. 3—Changes in probe coil coupling produce variations in rectified output of secondary winding. These are measured by microammeter to give readings of thickness. Reference rectifier, d-c amplifier, and cathode follower form feedback network controlling oscillator screen voltage to give practically constant output

that the oscillator serves as a constant-current source. Since the instrument monitors current in the secondary winding of the probe rather than the voltage across this winding, changes in lead length and in copper resistance have no effect upon the scale factor of the output of the probe.

To supply as much power as possible to the exciting coil, and to reduce the number of tuned elements, the exciting winding forms part of the oscillator plate tank inductance. The remaining inductance is obtained from the plate winding of the oscillator feedback transformer. This transformer is wound on a ½-inch form and consists of a 5-turn grid winding of No. 24 enamelled copper wire over a 50-turn plate winding of No. 30 enamelled ssc wire.

The combination of exciting coil, primary winding of the current transformer, and tank capacitor, form a parallel-resonant circuit. This design requires the oscillator tube itself to furnish only a small fraction of the current in the probe exciting coil.

Voltage from the secondary of the current transformer is rectified, compared to the d-c potential across a voltage regulator and fed to the d-c amplifier. Through a cathode follower, this amplifier controls the screen voltage of the oscillator tube. This regulator feedback circuit has a loop gain of the order of 100, so

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GENERAL SPECIFICATIONS

STANDARD RESISTANCE VALUES

In keeping with the trend toward standardization of electronic components, Type BT Resistors are supplied only in RMA (Radio Manufacturers' Association) Preferred Resistance Ranges, subject to minimum and maximum values listed for each type. RMA Ranges are identical to Joint Army-Navy War Standard Ranges.

COLOR CODING; IDENTIFICATION

BT Resistors are natural-bakelite color, non-gloss surface, with Resistance values are indicated by standard RMA Color Code Bands. Because of their small size, it is not practical to provide special stamping.

TOLERANCES. ± 10% standard. Available in ± 5% ± 10 % and ± 20% tolerance.

TEMPERATURE COEFFICIENT. The temperature coefficient of Type BT Resistors varies from 0.02%/°C for low ranges to 0.14%/°C for high ranges. The low temperature coefficients qualify Type BT Resistors under JAN-R-11 Resistance Temperature Characteristic "F", which is the better of the two grades of specified resistance-temperature characteristics. Type BT Resistors also successfully undergo the Temperature Cycling test of JAN-R-11.

VOLTAGE COEFFICIENT. Varies from 0.0% to 0.027% per volt, depending upon range and size of resistor. Type BT type fulfills the voltage coefficient requirement of the applicable JAN-R-11 specification.

NOISE LEVEL. Because of the inherent features of the Metallized filament and the low resistance contact of Type BT Resistors, noise level is uniform and consistently low.

OVERLOAD. 50% to 100% overload may be applied with nominal changes and return to initial value. Five-second overloads of 2.5 times rated load (double maximum continuous working voltage in the higher ranges) also result in negligible resistance change.

AGING. The pre-curing and stabilizing of the BT film eliminates to a very large degree the aging problem.

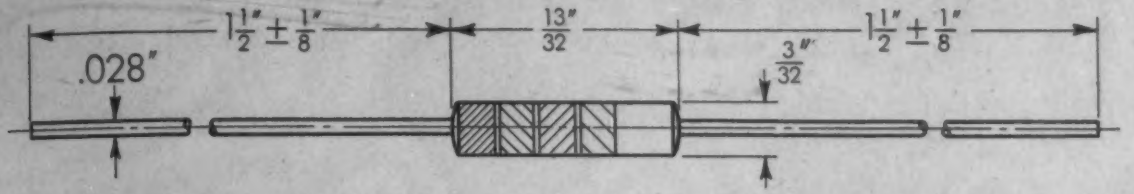
INSULATION BREAKDOWN VOLTAGE

All BT Resistors are conservatively rated, and, in all cases, ratings fulfill JAN-R-11 requirements.

HIGH ALTITUDE FLASHOVER. Type BT Resistors do not flash over when subjected to the JAN-R-11 Altitude Flashover test.

VIBRATION. BT Resistors show a resistance change less than the JAN-R-11 permissible maximum of 1% under the 5-hour vibration test.

TYPE BTR (⅓ WATT) *METALLIZED* INSULATED RESISTOR



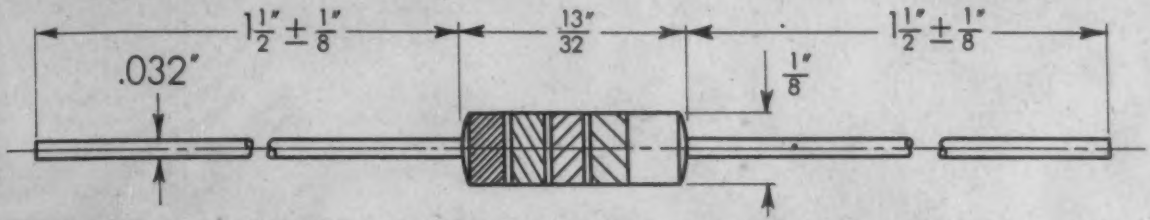
POWER AND VOLTAGE RATING: ⅓ watt (at 40°C. ambient) . . . 250 volts maximum continuous voltage. See Derating Curves, page 4 for higher ambients.

INSULATION BREAKDOWN VOLTAGE: 500 volts to ground.

STANDARD RESISTANCE VALUES: Minimum, 470 ohms; maximum, 22 megohms. Higher values on special order.

TEMPERATURE RISE: At ⅓-watt rating, 40°C. (At ¼-watt rating, 30°C.)

TYPE BTS (½ WATT) *METALLIZED* INSULATED RESISTOR



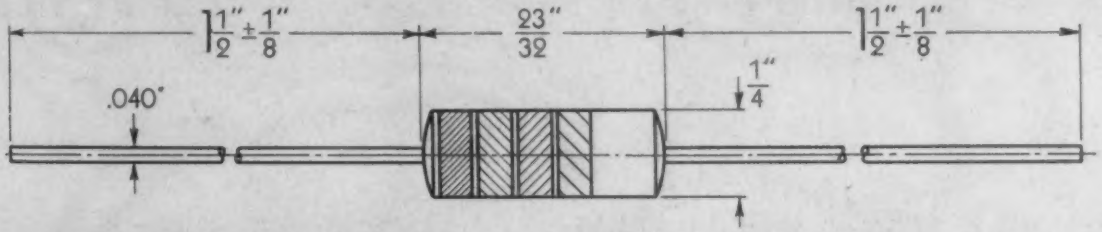
POWER AND VOLTAGE RATING: ½ watt (at 40°C. ambient) . . . 350 volts maximum continuous voltage. See Derating Curves, page 4 for higher ambients.

TEMPERATURE RISE AT RATED LOAD: 45°C.

STANDARD VALUES: Minimum, 470 ohms; maximum, 22 megohms. Higher values on special order.

INSULATION BREAKDOWN VOLTAGE: 750 volts to ground.

TYPE BTA (1 WATT) *METALLIZED* INSULATED RESISTOR



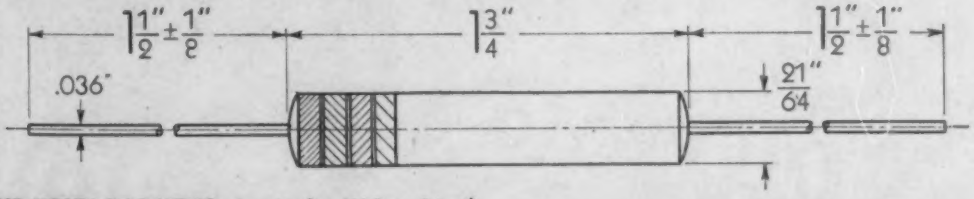
POWER AND VOLTAGE RATING: 1 watt (at 40°C. ambient) . . . 500 volts maximum continuous voltage. See Derating Curves, page 4 for higher ambients.

TEMPERATURE RISE AT RATED LOAD: 52°C.

STANDARD RESISTANCE VALUES: Minimum, 330 ohms; Maximum, 22 megohms. Higher values on special order.

INSULATION BREAKDOWN VOLTAGE: 1000 volts to ground.

TYPE BT-2 (2 WATT) *METALLIZED* INSULATED RESISTOR



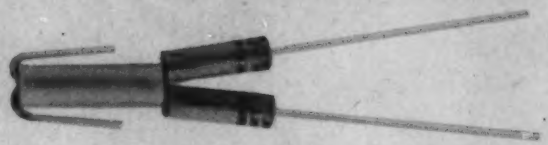
POWER AND VOLTAGE RATING: 2 watts (at 40°C. ambient) . . . 500 volts maximum continuous voltage. See Derating Curves, page 4, for higher ambients.

TEMPERATURE RISE AT RATED LOAD: 62°C.

STANDARD RESISTANCE VALUES: Minimum, 470 ohms; Maximum, 22 megohms. Higher values on special order.

INSULATION BREAKDOWN VOLTAGE: 1000 volts to ground.

MATCHED PAIR RESISTORS



IRC Matched Pairs—two resistors matched in series or parallel to as close as 1% initial accuracy provide a dependable low cost solution to close tolerance requirements.

Both IRC BT Insulated Filament-type resistors and type BW Insulated Wire Wounds are available in Matched Pairs. Tolerances from ± 5% to ± 1% can be furnished. They are supplied random color coded or unmarked, and held together for shipping by a paper band upon which is noted the resistance value and tolerance, or any two digit part number.

IRC Matched Pairs are widely used as meter multipliers, and in many other close tolerance applications where low cost is an important factor. When ordering, the higher ohmic values should be specified to be matched in series and the lower values in parallel.

Due to temperature coefficients and possible variations in resistance value as a result of testing conditions, type BT Matched Pairs are not returnable for out-of-tolerance measurement unless variations exceed ± 3½% from nominal value.

NOTE: Matched Pairs should not be soldered closer than ¼" from body of the resistors, mounted against any heat dissipating component, or used at full rating of the resistors—as any one of these conditions may force the resistors out of tolerance.

MATCHED PAIR RESISTANCE LIMITS

Parallel Matched Pairs

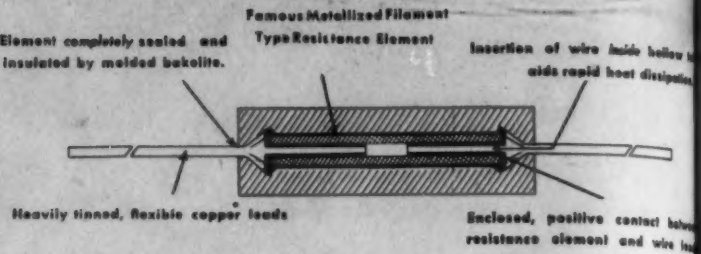
Type	Minimum Resistance	Maximum Resistance
BW-½	5 Ohms	410 Ohms
BW-1	2.5 Ohms	2550 Ohms
BW-2	3.75 Ohms	4100 Ohms
BTS	235 Ohms	10.0 Megohms
BTA	165 Ohms	10.0 Megohms
BT-2	235 Ohms	10.0 Megohms

Series Matched Pairs

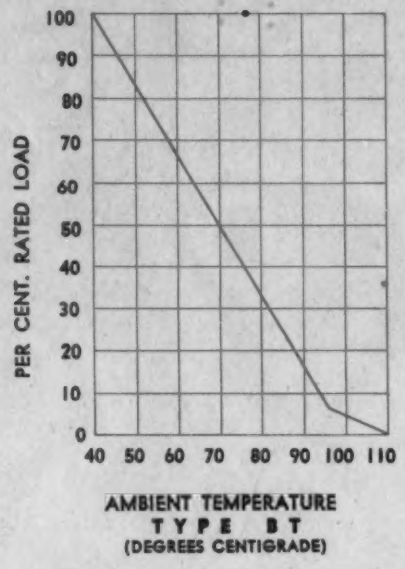
Type	Minimum Resistance	Maximum Resistance
BW-½	20 Ohms	1640 Ohms
BW-1	10 Ohms	10,200 Ohms
BW-2	15 Ohms	16,400 Ohms
BTS	940 Ohms	40.0 Megohms
BTA	660 Ohms	40.0 Megohms
BT-2	940 Ohms	40.0 Megohms

IRC TYPE BT RESISTORS

CONSTRUCTION


Famous Metallized Filament Type Resistance Element
Element completely sealed and insulated by molded bakelite.
Insertion of wire inside hollow
aids rapid heat dissipation
Heavily tinned, flexible copper leads
Enclosed, positive contact

DERATING CURVE FOR HIGH AMBIENT TEMPERATURES



Ratings of Type BT are based on an ambient temperature of 40°C. Ambient conditions as well as voltage ratings and actual power requirements should be considered when determining the proper size of resistor for any application. When BT's are used at ambient temperatures exceeding 40°C., load should not exceed that indicated by the JAN-R Derating Curve reproduced here.

STANDARD VALUES TYPES BT AND BW

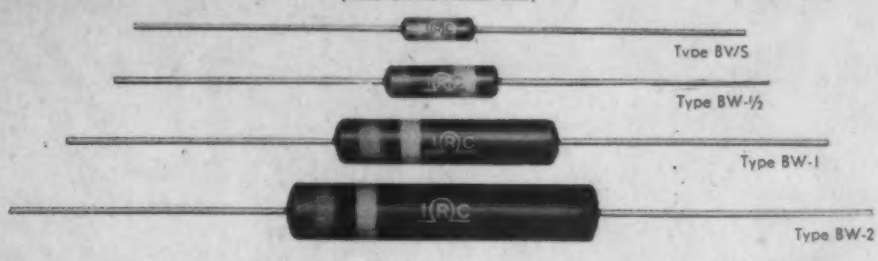
(In accordance with JAN-R-11 and RMA Preferred Resistance Values)

Because of general adoption of these values, it has become necessary to standardize all Type BT and BW production and stocks on JAN-R-11 values. Available ranges for each type of BT and BW Resistor are limited by the minimum and maximum values listed for each type.

	OHMS						MEGOHMS		
RMA No.	0 to 1.0	1 to 9.1	10 to 91	100 to 910	1,000 to 9,100	10,000 to 91,000	0.1 to 0.91	1.0 to 9.1	10 to 91
10	—	1.0	10	100	1,000	10,000	0.1	1.0	10.0
11	—	1.1	11	110	1,100	11,000	0.11	1.1	11.0
12	—	1.2	12	120	1,200	12,000	0.12	1.2	12.0
13	—	1.3	13	130	1,300	13,000	0.13	1.3	13.0
15	—	1.5	15	150	1,500	15,000	0.15	1.5	15.0
16	—	1.6	16	160	1,600	16,000	0.16	1.6	16.0
18	—	1.8	18	180	1,800	18,000	0.18	1.8	18.0
20	—	2.0	20	200	2,000	20,000	0.20	2.0	20.0
22	—	2.2	22	220	2,200	22,000	0.22	2.2	22.0
24	0.24	2.4	24	240	2,400	24,000	0.24	2.4	21.0
27	0.27	2.7	27	270	2,700	27,000	0.27	2.7	27.0
30	0.30	3.0	30	300	3,000	30,000	0.30	3.0	30.0
33	0.33	3.3	33	330	3,300	33,000	0.33	3.3	33.0
36	0.36	3.6	36	360	3,600	36,000	0.36	3.6	36.0
39	0.39	3.9	39	390	3,900	39,000	0.39	3.9	39.0
43	0.43	4.3	43	430	4,300	43,000	0.43	4.3	43.0
47	0.47	4.7	47	470	4,700	47,000	0.47	4.7	47.0
51	0.51	5.1	51	510	5,100	51,000	0.51	5.1	51.0
56	0.56	5.6	56	560	5,600	56,000	0.56	5.6	56.0
62	0.62	6.2	62	620	6,200	62,000	0.62	6.2	62.0
68	0.68	6.8	68	680	6,800	68,000	0.68	6.8	68.0
75	0.75	7.5	75	750	7,500	75,000	0.75	7.5	75.0
82	0.82	8.2	82	820	8,200	82,000	0.82	8.2	82.0
91	0.91	9.1	91	910	9,100	91,000	0.91	9.1	91.0

TYPE BW INSULATED WIRE WOUND RESISTORS

(Illustrations Actual Size)



GENERAL SPECIFICATIONS AND CHARACTERISTICS

TOLERANCES. ± 10% is standard. Values above 10 ohms available in ± 5% tolerance. For closer tolerance requirements, see paragraph "Matched Pairs."

COLOR CODING; IDENTIFICATION. Type BW Resistors are dark brown in color, with a waxed, non-gloss surface. Resistance values indicated by standard RMA Color Code bands. It is not practical to provide special stamping because of their small size.

STANDARD RESISTANCE VALUES. RMA Preferred Ranges, subject to minimum and maximum values as listed for each BW type.

NOISE. Negligible.

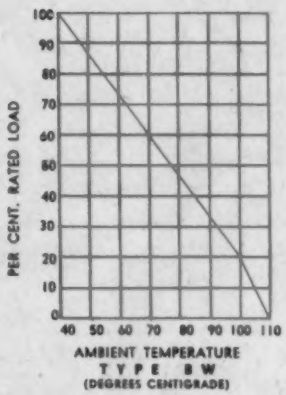
HUMIDITY. Designed to withstand abnormal atmospheric conditions.

OVERLOAD. 50% to 100% overloads may be applied with negligible changes and return to initial value.

AGING. Negligible.

DERATING

Ratings of Type BW Resistors are based on an ambient temperature of 40°C. When BW's are used at ambient temperatures exceeding 40°C., load should not exceed that indicated by the JAN-R Derating Curve reproduced here.



FREQUENCY CHARACTERISTICS. The inductance of BW Resistors is relatively low, making them suitable for use at carrier frequencies. The following table gives the approximate inductance for maximum and minimum resistance values.

TYPE	Minimum Resistance	Approx. Inductance in Microhenries	Maximum Resistance	Approx. Inductance in Microhenries
BWS	1.0 Ohm	0.08 mh.	300 Ohms	1.3 mh.
BW-½	0.24 Ohm	0.02 mh.	820 Ohms	4.02 mh.
BW-1	0.47 Ohm	0.20 mh.	5100 Ohms	60.0 mh.
BW-2	1.0 Ohm	0.50 mh.	8200 Ohms	115.0 mh.

Type BWS

***NOTE:** Type BWS will not be available for general use during the war. Samples supplied for postwar designs upon request.*

POWER RATING: ¼ watt (at 40°C. ambient).

DIMENSIONS: Length $\frac{13}{32}$". Diameter ⅛". Lead length 1½". ± ⅛". Lead diameter 0.032".

TEMPERATURE RISE AT RATED LOAD: 30°C.

STANDARD RESISTANCE VALUES: Minimum, 1.0 ohm, Maximum, 300 ohms.

Type BW-½

JAN-R-184 TYPE: RU3. **POWER RATING:** ½ watt (at 40°C. ambient).

DIMENSIONS: Length ⅝". Diameter 3/16". Lead length 1½". ± ⅛". Lead diameter 0.032".

TEMPERATURE RISE AT RATED LOAD: 50°C.

INSULATION: 700 volts breakdown to ground.

STANDARD RESISTANCE VALUES: Minimum, 0.24 ohm. Maximum, 820 ohms. **JAN-R-184:** Maximum, 420 ohms.

Type BW-1

JAN-R-184 TYPE: RU4. **POWER RATING:** 1 watt (at 40°C. ambient).

DIMENSIONS: Length 1¼". Diameter ¼". Lead length 1½". ±⅛". Lead diameter 0.036".

TEMPERATURE RISE AT RATED LOAD: 65°C.

INSULATION: 1000 volts breakdown to ground.

STANDARD RESISTANCE VALUES: Minimum, 0.47 ohm. Maximum, 5100 ohms. **JAN-R-184:** Maximum, 2200 ohms.

Type BW-2

JAN-R-184 TYPE: RU6. **POWER RATING:** 2-watts.

DIMENSIONS: Length 1¾". Diameter $\frac{23}{32}$". Lead length 1½". ± ⅛". Lead diameter 0.036".

TEMPERATURE RISE AT RATED LOAD: 90°C.

INSULATION: 1000 volts breakdown to ground.

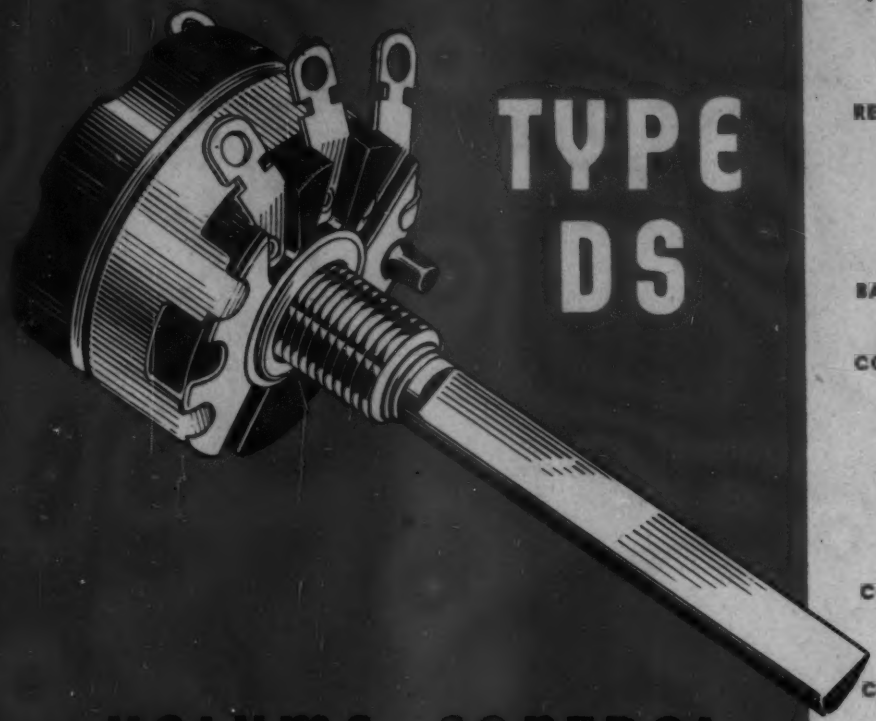
STANDARD RESISTANCE VALUES: Minimum, 1.0 ohm. Maximum, 8200 ohms. **JAN-R-184:** Maximum, 3300 ohms.

TEMPERATURE COEFFICIENT. To cover a wide range of resistance values, it is necessary to use several different wire alloys, which have different temperature coefficients, as indicated by the following table.

TYPE	0.12%/°C	0.038%/°C	0.002%/°C	0.017%/°C
BWS		1.0 Ohm to 3.0 Ohms	3.3 Ohms to 10.0 Ohms	11 Ohms to 300 Ohms
BW-½		0.24 Ohm to 0.75 Ohm	0.82 Ohm to 5.1 Ohms	5.6 Ohms to 820 Ohms
BW-1	0.51 Ohm to 1.10 Ohms	1.2 Ohms to 3.6 Ohms	3.9 Ohms to 36.0 Ohms	39.0 Ohms to 5100 Ohms
BW-2	1.0 Ohm to 2.0 Ohms	2.2 Ohms to 6.8 Ohms	7.5 Ohms to 51.0 Ohms	56 Ohms to 8200 Ohms

CATALOG DATA BULLETIN

Important information for Engineering and Purchasing Depts. Please file with your IRC Catalog.
INTERNATIONAL RESISTANCE CO., 401 N. Broad St., Philadelphia 8, Pa., U. S. A.
In Canada: International Resistance Co., Ltd., Toronto, Licensee



TYPE DS

VOLUME CONTROL POTENTIOMETER

The IRC type DS is a high quality 1½" diameter control conservatively rated at 1/3 watt over the entire element. Nothing has been sacrificed in the design or manufacture of this control. The finest materials are employed, and its compact design embodies many exclusive IRC engineering features.

The resistance coating is an adaptation of the IRC filament principle, famous for its stability. A smooth, moisture-proof element is provided by bonding the resistance material to a bakelite base. The conventional type collector ring is supplanted by a silent spiral spring in the DS control. This positive type of electrical connection eliminates sliding metal-to-metal contact, the primary source of control noise. Contact with element is made by a unique multi-finger contactor utilizing the "knee-action" engineering principle.

IRC is the world's largest exclusive manufacturer of resistance products. Over twenty years' experience, engineering "know-how" and manufacturing technique are incorporated in the production of each DS control. An unsurpassed record of dependability over long operational life, low noise level and stability have made the IRC type DS the industry's "number one" control-potentiometer for applications requiring quality components.

CONSTRUCTION

RESISTANCE ELEMENT
Resistance material permanently bonded to bakelite base by carefully controlled heat treatment process, resulting in a smooth, moisture-proof resistance element of excellent stability.

BASE
Highest grade molded bakelite.

CONTACTOR
Exclusive IRC five-finger contactor consisting of five tinned phosphor bronze spring wires. Each finger operates independently on "knee-action" principle, assuring positive uniform contact. Contactor surfaces are rounded and smooth, minimizing noise and wear.

CONTACTS
All parts making fixed pressure contact silver plated to prevent corrosion.

CONNECTOR
Permanent connection is established between contactor and terminal with, silent spiral spring connector—an exclusive IRC feature. This advanced form of design eliminates sliding metal-to-metal contacts, thus removing the most troublesome source of control noise.

THRUST WASHER
Coil spring thrust washer eliminates shaft wobble and "end play."

CHARACTERISTICS

AGEING
Control element is aged during processing, thus minimizing change during service to 1 or 2%.

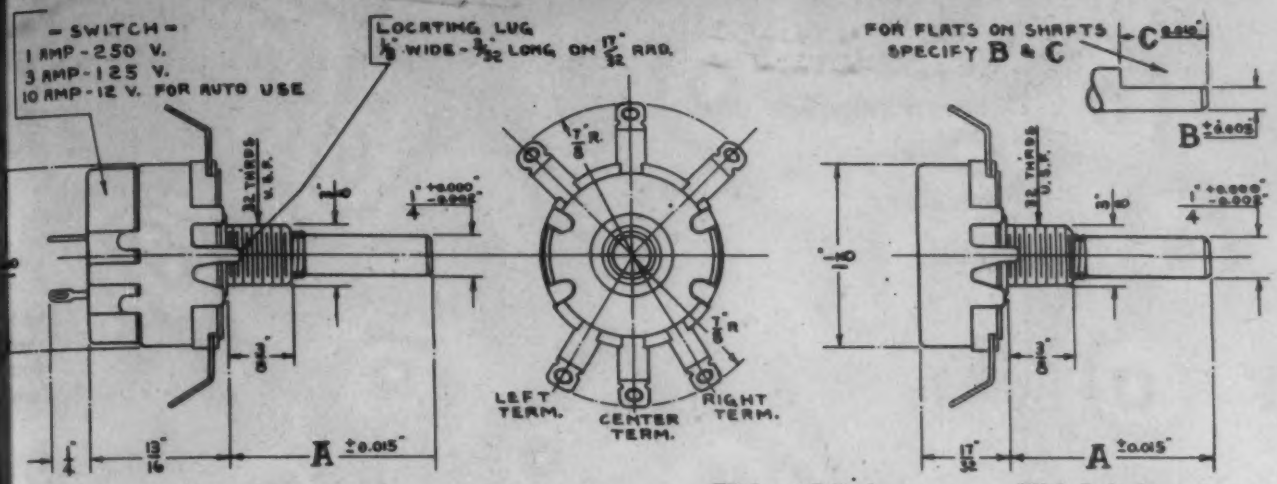
WEAR
Average variation is 5% after 25,000 rotations—slight increase in percentage as rotations increase.

HUMIDITY
Exposure to most humid climatic conditions for long periods causes positive change in range of approximately 10%. Control returns to initial value upon drying.

NOISE
Silent Spiral Spring Connector and Five Finger Contactor reduce contact noise to a negligible minimum.

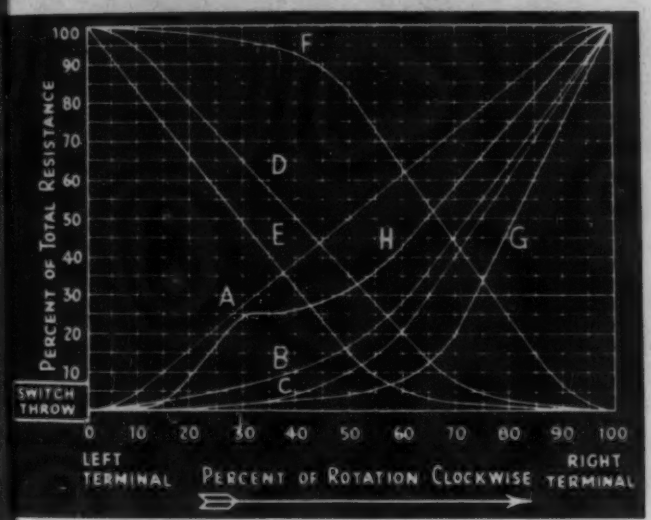
TEMPERATURE COEFFICIENT
.02%/°C. to .05%/°C.

SPECIFICATIONS TYPE DS VOLUME CONTROLS


- SWITCH -
1 AMP - 250 V.
3 AMP - 125 V.
10 AMP - 12 V. FOR AUTO USE
LOCATING LUG
WIDE - LONG ON RAD.
FOR FLATS ON SHAFTS SPECIFY B & C
LEFT TERM.
CENTER TERM.
RIGHT TERM.
A ±0.015"

	Without Switch	With Switch
Dual Control: Depth from Mounting face	1 1/16	1 11/16
Triple Control: Depth from Mounting face	1 11/16	1 7/8

STANDARD TAPERS



Special Tapers Available—
Only Linear Taper below 500 ohms.

SWITCH
Standard S.P.S.T.
Special D.P.S.T.

LOCATING PINS
One pin standard—two or none as specified.

GANGED CONTROLS
Type D S may be ganged in any combination required.

CONCENTRIC DUAL CONTROLS
Available with outer shaft controlling panel.

RESISTANCE VALUE
200 ohms to 10 megohms.

TOLERANCES
± 20% standard; ± 3% Rotational Tolerance.

POWER DISSIPATION
⅓ watt over entire element.

ROTATION
300° Standard.

SHAFT
¼" diameter—length—Dim. A as required—Screw Driver Slot — Flats, etc., available—Standard material Brass.

BUSHING
Brass — diameter ⅜" thread, 32 per inch—Standard length ⅜"; special ¼", ½" and ⅝".

TAPS
One or two available as required—Standard tap location: 35%, 50%, 65%.

COVER
Cover Grounded to Bushing.

INTERNATIONAL RESISTANCE CO.

401 NORTH BROAD STREET
PHILADELPHIA 8, PA. U. S. A.
TELEPHONE: WA 2-3166

IN CANADA: INTERNATIONAL RESISTANCE CO., LTD.
11 KING STREET WEST, TORONTO, LICENSEE

BRANCH OFFICE: 165 BROADWAY, NEW YORK, N. Y., Courtland 7-5020

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James P. Hermann Co., 1234 Folsom St., SAN FRANCISCO, Calif., Market 6166
David M. Lee, 2626 Second Ave., SEATTLE, Wash., Main 5512

CATALOG DATA BULLETIN

Important information for Engineering and Purchasing Depts. Please file with your IRC Catalog.
INTERNATIONAL RESISTANCE CO., 401 N. Broad St., Philadelphia 8, Pa., U. S. A.
In Canada: International Resistance Co., Ltd., Toronto, Licensee

IRC WIRE WOUND CONTROLS

2 WATT RHEOSTAT-POTENTIOMETER

The IRC Type W Control is designed for long, dependable service and balanced performance in every characteristic. A 2 watt variable wire wound unit, this control provides maximum adaptability to most rheostat and potentiometer applications within its power rating. It's small 1¼" by 9/16" design features the exclusive IRC spiral spring connector, a long-wearing alloy contactor, and welded connections between resistance element wire and terminals.

The Type W Control is widely used in many electronic applications, and with center tap is particularly suited for television receivers as vertical and horizontal centering control.

The highest grade alloy wire is wound with uniform spacing and tension on specially treated bakelite to form a precision resistance element. Element is securely seated in grooved bakelite base. Contactor slides on edge of element which prevents loosening of wire. Compact construction insures efficient electrical and mechanical operation even when subjected to severe vibration.

Combination metal and bakelite housing provides maximum heat dissipation as well as protection against dust and mechanical damage. Effects of humidity, temperature and aging are negligible.

CHARACTERISTICS

RESISTANCE VALUES. 2 ohms to 10,000 ohms.

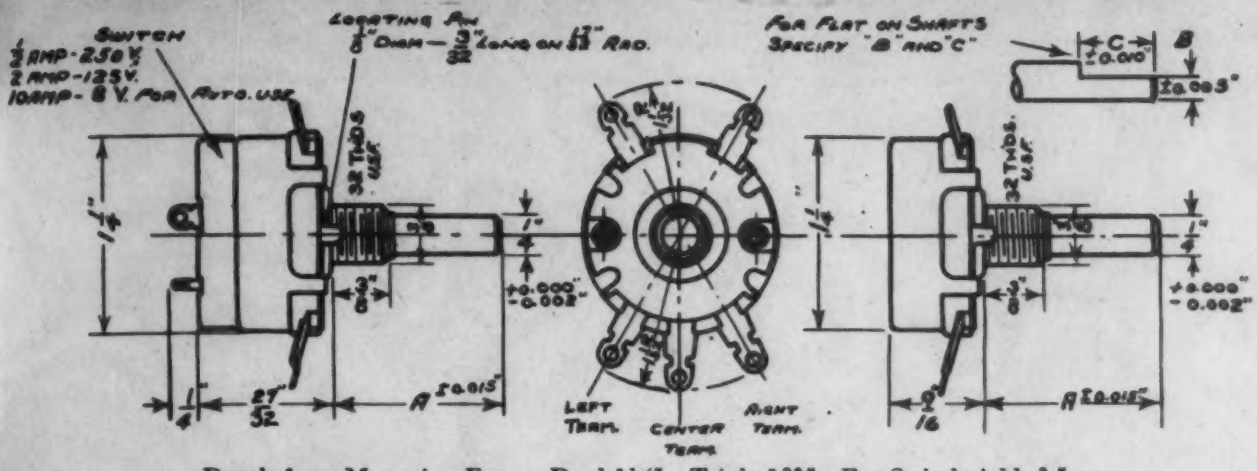
TOLERANCES. ± 10% standard; ± 5% available at extra cost.

POWER RATING. 2 watts. This rating allows 70°C. temperature rise at hottest spot on winding from a 25°C. ambient temperature.

TAPS. One tap is available at either of the following positions: 40%, 50%, or 60% of electrical rotation.

TAPERS. Linear taper is standard. Tolerance linearity is within ±3%. Special tapers available at extra cost.

SPECIFICATIONS WIRE WOUND CONTROLS



Depth from Mounting Face. Dual 1¼" Triple 1 3/32" For Switch Add 1/32"

SIZE. 1¼" diameter; depth behind panel, 9/16".

RESISTANCE ELEMENT. Copper-nickel or nickel-chrome alloy wire wound uniformly under tension on specially treated bakelite. Element securely seated in grooved bakelite base. Resistance wire welded to terminals for perfect contact.

CONTACTOR. Long-wearing contactor of unique design provides uniform pressure at any point, providing smooth progression of resistance. Contactor is riveted to spring connector which in turn is riveted to center terminal. This insures long life and absolute dependability.

ROTATION. Total rotation 295°; effective rotation 265° without switch, 218° with switch.

SHAFT. Brass shaft is standard; aluminum, steel, or stainless steel available on special order. ¼" diameter — length as required. Screw driver slot available. Flat available — specify dimensions "B" and "C" as shown on above drawing. Shaft is fully insulated from terminals.

BUSHING. Brass bushing. Diameter ⅜", thread 32 per inch. Standard length is ⅜"; ¼", ½" or ⅝" lengths available on special order.

SWITCH. S.P.S.T. is standard; S.P.D.T. and D.P.S.T. available on request. All switches carry Underwriters' approval.

LOCATING PIN. One pin is standard; either two or none may be had when specified.

COVER. Cover is grounded to bushing.

OFF POSITION. Off position is available when specified.

GANGED CONTROLS. The Type W is available as a dual or triple control and may be "ganged" with the Type C carbon control.

TERMINALS. Terminals are hot tin dipped. Three are standard; one may be omitted when specified.

IRC Control	Resistance	Max. Current (Amps.)
W-2	2	1.000
W-3	3	.815
W-5	5	.630
W-6	6	.560
W-8	8	.500
W-10	10	.450
W-15	15	.370
W-20	20	.320
W-25	25	.285
W-30	30	.260
W-40	40	.225
W-50	50	.200
W-60	60	.183
W-75	75	.164
W-100	100	.142
W-200	200	.100
W-300	300	.083
W-400	400	.071
W-500	500	.063
W-750	750	.052
W-1000	1000	.045
W-2000	2000	.032
W-3000	3000	.026
W-4000	4000	.022
W-5000	5000	.020
W-7500	7500	.016
W-10000	10000	.014

These standard values are available from IRC distributors' stocks. Intermediate values are manufactured to special order.

INTERNATIONAL RESISTANCE CO.

401 NORTH BROAD STREET
PHILADELPHIA 8, PA. U. S. A.
TELEPHONE: WA 2-2166

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Kenmore 1370

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BUFFALO, N. Y.

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CHICAGO, Ill.
Franklin 4818

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CLEVELAND, Ohio
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Riverside 1272

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Spruce 9368

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Madison 8086

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Broadway 6770

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Drexel 8233

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Court 0121

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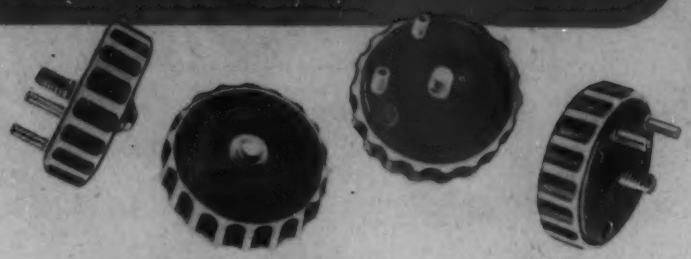
ST. LOUIS, Mo.
Central 6340

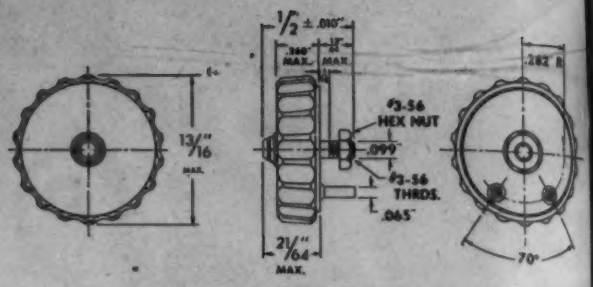
J. U. McCarthy
1722 Hillcrest Ave.
ST. PAUL, Minn.
Emerson 2611

James P. Harmens Co.
1334 Folsom St.
SAN FRANCISCO, Calif.
Market 4166

David M. Lee
262a Second Ave.
SEATTLE, Wash.
Main 5552

TYPE H FINGERTIP CONTROL





DIMENSIONS, TYPE H CONTROL

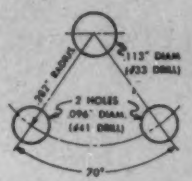
RESISTANCE ELEMENT: IRC Metallized coating, bonded to a phenolic strip, cured and stabilized at high temperature, in the same manner as IRC Type CS and D Controls. *Integral molding of this element with the phenolic base* results in improved strength, more efficient heat dissipation, and increased resistance to humidity.

CONTACTOR: A two-finger, ball-point, radial contact, of silver-plated spring alloy.

TERMINALS: Center Contact is a silver-plated brass stud with the external portion provided with No. 3-56 thread. The shoulder of the internal portion of the stud forms the bearing surface on which the moving contactor rotates when driven by the cover. The end terminals are silver-plated brass.

ROTATION: 290° rotation is standard.

POWER RATING: 0.25 Watts for linear taper.



Recommended mounting template for Type H Control

MOUNTING: Designed for mounting on an insulating bracket or panel having a 1/16" min. thickness or a max. thickness of 7/64". The center terminal, provided with a No. 3-56 Hex nut, is the principal mounting means. A three-hole mounting is recommended with the two end terminals acting as locating devices. If a suitable grommet or insulating bushing is used, the control can be mounted on a metal panel.

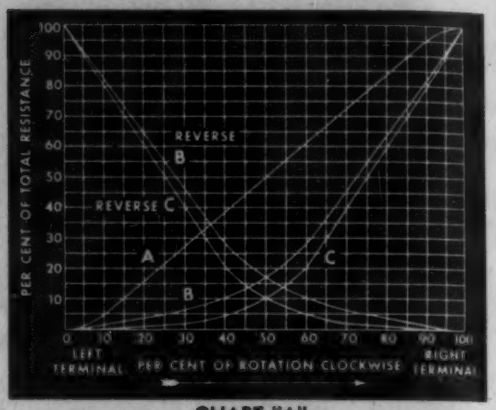


CHART "A"

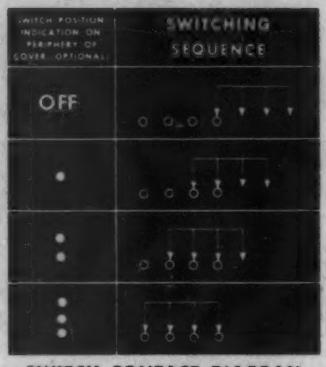
RESISTANCE VALUE and TAPERS: Available resistance values depend upon tapers, as listed below. Type H Controls can be provided with linear taper or any of the standard audio tapers, such as Curve B, Curve C, Reverse B or Reverse C, as shown in Chart "A." NOTE: Reversed B and Reversed C Curves show resistance change as measured between Clockwise and Center Terminals.

Curve	Min. Res.	Max. Res.
A	500 ohms	5.0 meg.
B or Reverse B	750 ohms	3.0 meg.
C or Reverse C	1000 ohms	2.0 meg.

STANDARD TOLERANCE: ± 20%

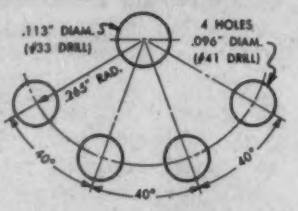
TYPE SH FINGERTIP SWITCH

TYPE OF SWITCH: Type SH is a three-position switch. In addition to the "OFF" position, there are three operating positions, as shown in the Switch Contact Diagram. In Position 1, the first 2 terminals are connected together; in Position 2, the first, second and third terminals are shorted together, and in Position 3, all four of the terminals are connected together.

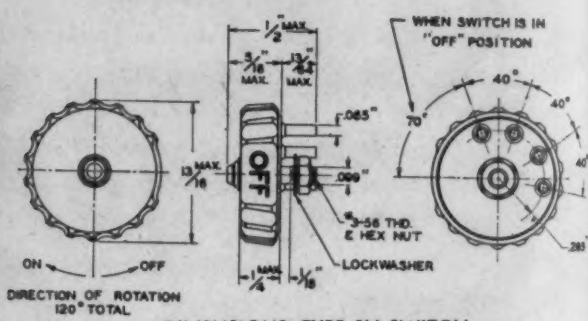


SWITCH CONTACT DIAGRAM

MOUNTING: The central mounting stud, molded into the base, has a No. 3-56 thread and is provided with a lockwasher and a No. 3-56 Hex nut for mounting purposes. The Type SH Switch is designed to be mounted on an insulating bracket or panel having a 1/16" min. thickness, or a max. thickness of 7/64". As with the Type H Control, the terminals of the switch may function as locating devices in mounting.



Recommended mounting template for Type SH Switch



DIMENSIONS, TYPE SH SWITCH

CONTACTOR: Silver-plated spring alloy, web-shaped contact.

TERMINALS: The four silver-plated brass terminals are molded into a phenolic base. The central mounting stud in the switch is "live," as it is in direct contact with the contactor, but is not intended to be used as an external wiring connection.

ROTATION: Total rotation is 120°; 40° rotation per position.

DETENT: Positive in all positions, including "OFF" position.

CONTACT RATING: Suitable for filament circuit switch in pocket radios; for tone control circuits, or for combination filament switch and tone control applications.

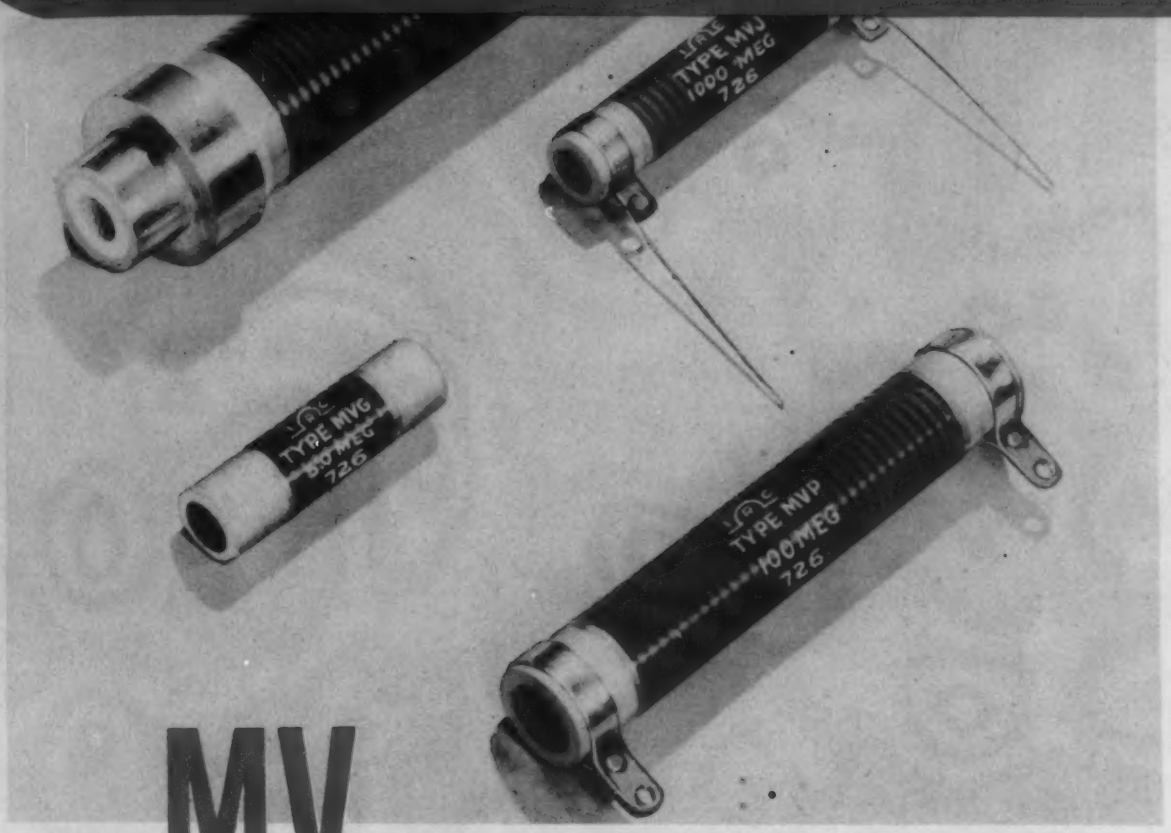
IRC

CATALOG DATA BULLETIN

Important information for Engineering and Purchasing Depts. Please file with your IRC Catalog.

INTERNATIONAL RESISTANCE CO., 401 N. Broad St., Philadelphia 8, Pa., U. S. A.

In Canada: International Resistance Co., Ltd., Toronto, Licensee



TYPE MV HIGH VOLTAGE RESISTORS

IRC Type MV Resistors are designed for high voltage applications where high resistance and power are required. Unique application of IRC's famous filament resistance coating in helical turns on a ceramic tube provides a conducting path of long effective length.

The long resistance path makes it possible to produce a unit of high resistance value with resistance materials having relatively low specific resistance. For this reason, Type MV Resistors have exceptional stability even in very high resistance values. The long resistance path permits the use of high voltage on the resistor while keeping the voltage per unit length of path comparatively low.

HANDLING. Type MV Resistors will stand ordinary handling; however, it is recommended that the units be installed after other mechanical work has been completed, and that the protective wrapping on the body of the resistor be left in place until the unit has been installed in the equipment.

HUMIDITY. General protective coatings of special varnish, baked individually at high temperature, provide protection against the effects of abnormal humidity. Maximum resistance change of ±5% can be expected due to humidity. Resistance will return to original value when humidity conditions become normal.

INSULATION. Base is ceramic with excellent high voltage characteristics. The spacing of the turns of the helical conducting path is designed to provide adequate protection against breakdowns between turns.

SPECIFICATIONS TYPE MV HIGH VOLTAGE RESISTORS

TYPE MV RESISTORS
WITH LUG TERMINALS OR COLLOIDAL SILVER TERMINALS

TYPE	TERMINAL TYPE AND DRAWING NO.	POWER RATING	PEAK VOLTAGE RATING	MINIMUM AVAILABLE RESISTANCE AT ±10% or ±20% TOLERANCE	MINIMUM AVAILABLE RESISTANCE AT ±5% TOLERANCE	MAXIMUM AVAILABLE RESISTANCE (See Note 1, Below, for Tolerance Limitations)	DIMENSIONS CERAMIC LENGTH	DIMENSIONS RESISTOR BODY DIAMETER	DIMENSIONS CERAMIC I.D.	DIMENSIONS WIDTH OF COLLOIDAL SILVER BAND #10 TERMINALS, Fig. 5
MVF-12	#12, Fig. 1	2 watts	5,000	2,500 ohms	25,000 ohms	250 megohms	1⅝" ±1/32"	5/16" ±1/32"	5/16"	5/16" ±1/16"
MVF-13	#13, Fig. 3									
MVG-13	#13, Fig. 3	4 watts	5,000	10,000 ohms	0.1 megohm	700 megohms	2" ±1/32"	5/16" ±1/32"	⅜"	5/16" ±1/16"
MVG-15	#15, Fig. 5									
MVG-16	#16, Fig. 2									
MVG-17	#17, Fig. 4									
MVJ-15	#15, Fig. 5	5 watts	10,000	20,000 ohms	0.2 megohm	1,000 megohms	3" ±1/32"	5/16" ±1/32"	⅜"	5/16" ±1/16"
MVJ-16	#16, Fig. 2									
MVJ-17	#17, Fig. 4									
MVP-15	#15, Fig. 5	10 watts	15,000	50,000 ohms	0.4 megohm	2,000 megohms	4½" ±1/16"	⅜" ±1/32"	½"	5/16" ±1/16"
MVP-16	#16, Fig. 2									
MVP-17	#17, Fig. 4									
MVA-15	#15, Fig. 5	20 watts	25,000	0.2 megohm	1.0 megohm	4,000 megohms	6½" ±1/16"	1⅛" ±1/32"	⅝"	5/16" ±1/16"
MVA-16	#16, Fig. 2									
MVA-17	#17, Fig. 4									
MVO-15	#15, Fig. 5	30 watts	50,000	0.4 megohm	2.0 megohms	8,000 megohms	10⅜" ±1/16"	1⅛" ±1/32"	⅝"	5/16" ±1/16"
MVO-16	#16, Fig. 2									
MVO-17	#17, Fig. 4									
MVR-15	#15, Fig. 5	60 watts	100,000	1.0 megohm	7.0 megohms	20,000 megohms	18½" ±1/16"	2" ±5/64"	1⅞16"	⅝" ±1/16"
MVR-17	#17, Fig. 4									

Note 1:—At ±5% tolerance, 1000 megohms is the maximum available. (Except where maximum available tabulated is less than 1,000 megohms.) At ±10% tolerance, 10,000 megohms is the maximum available. (Except where maximum available tabulated is less than 10,000 megohms.) Above 10,000 megohms, ±20% is the only available tolerance.

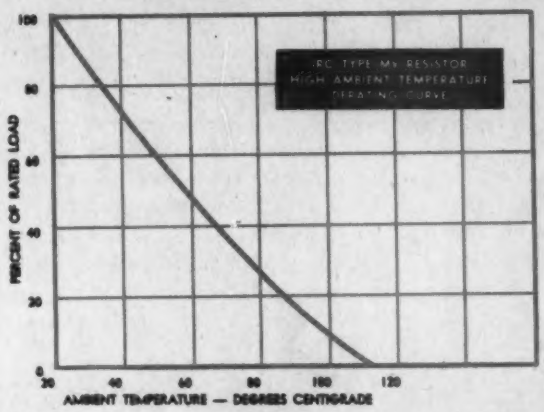
WITH LUG TERMINALS OR COLLOIDAL SILVER TERMINALS ↓ **WITH FERRULE TERMINALS #5, #7, and #8**

TYPE MV RESISTORS
WITH FERRULE TERMINALS, #5, #7 AND #8

TYPE	POWER RATING	PEAK VOLTAGE RATING	MINIMUM AVAILABLE RESISTANCE AT ±10% or ±20% TOLERANCE	MINIMUM AVAILABLE RESISTANCE AT ±5% TOLERANCE	MAXIMUM AVAILABLE RESISTANCE (See Note 1, Below, for Tolerance Limitations)	OUTLINE DRAWING	DIMENSIONS OVERALL LENGTH "A"	DIMENSIONS NOMINAL DIAMETER "B"	DIMENSIONS FERRULE SPACING "C"	DIMENSIONS FERRULE DIAMETER "D"	DIMENSIONS FERRULE LENGTH "E"
MVS-5	4.0 watts	5,000	10,000 ohms	0.1 megohm	500 meg.	Fig. 6	2 1/16" ±1/8"	1 1/16" ±1/32"	1⅜" ±1/16"	9/16" ±1/32"	½" ±1/16"-0"
MVT-5	5.0 watts	7,500	15,000 ohms	0.15 megohm	800 meg.	"	3" ±1/8"	1 1/16" ±1/32"	1 11/16" ±1/16"	9/16" ±1/32"	½" ±1/16"-0"
MVB-7	7.5 watts	*12,000	50,000 ohms	0.4 megohm	1,500 meg.	"	4½" ±1/8"	1" ±1/32"	3 1/16" ±1/16"	1 3/16" ±1/32"	½" ±1/16"-0"
MVD-7	10.0 watts	15,000	0.1 megohm	0.7 megohm	2,000 meg.	"	5 9/16" ±1/8"	1" ±1/32"	4 1/16" ±1/16"	1 3/16" ±1/32"	½" ±1/16"-0"
MVE-8	20.0 watts	25,000	0.2 megohm	1.0 megohm	4,000 meg.	"	7⅛" ±1/8"	1⅛" ±1/32"	6 1/16" ±1/16"	1⅛" ±1/32"	½" ±1/16"-0"
MVE-8	25.0 watts	40,000	0.3 megohm	1.5 megohms	6,000 meg.	"	9 11/16" ±1/8"	1⅛" ±1/32"	8⅜" ±1/16"	1⅛" ±1/32"	½" ±1/16"-0"
MVO-7	30.0 watts	50,000	0.4 megohm	2.0 megohms	8,000 meg.	"	12" ±1/8"	1⅛" ±1/32"	10 13/16" ±1/16"	1 3/16" ±1/32"	½" ±1/16"-0"
MVR-8	90.0 watts	100,000	1.0 megohm	7.0 megohms	20,000 meg.	"	19⅜" ±1/16"	2" ±3/64"	18½" ±1/32"	1⅛" ±1/32"	9/16" ±1/32"-0"

Note 1:—For ±5% tolerance, 1,000 megohms is maximum available. (Except where maximum available, tabulated above, is less than 1,000 megohms.) For ±10% tolerance, 10,000 megohms is maximum available. (Except where maximum available, tabulated above, is less than 10,000 megohms.) Above 10,000 megohms, ±20% is the only available tolerance.

All above resistor types can be supplied in resistance ranges above standard to a maximum of 1,000,000 megohms. Tolerance ± 20%. Prices special depending on resistance range.

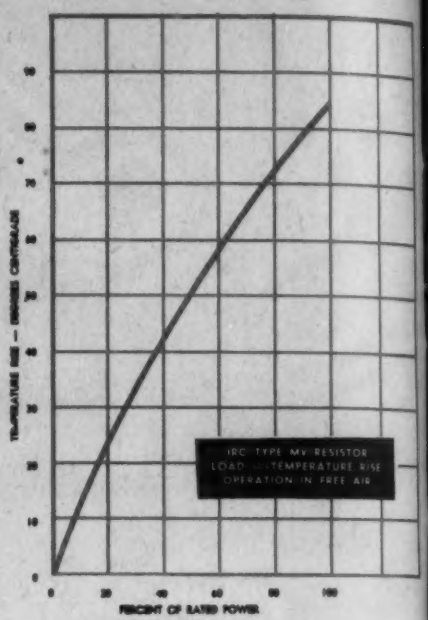


DERATING

When MV Resistors are operating at any ambient higher than 20° C., it is recommended that they be derated according to the following curve.

POWER RATINGS.

The ratings shown in the specification chart C. ambient and are based on free air operation at 20° should not be exceeded.



TEMPERATURE COEFFICIENT. —.005%° C. for low resistance to —.07%° C. for high resistance values.

AGING. Pre-curing and stabilizing of resistance coating at high temperature eliminates appreciable aging. Laboratory tests and field experience indicate that aging rarely exceeds ±3% of the original value.

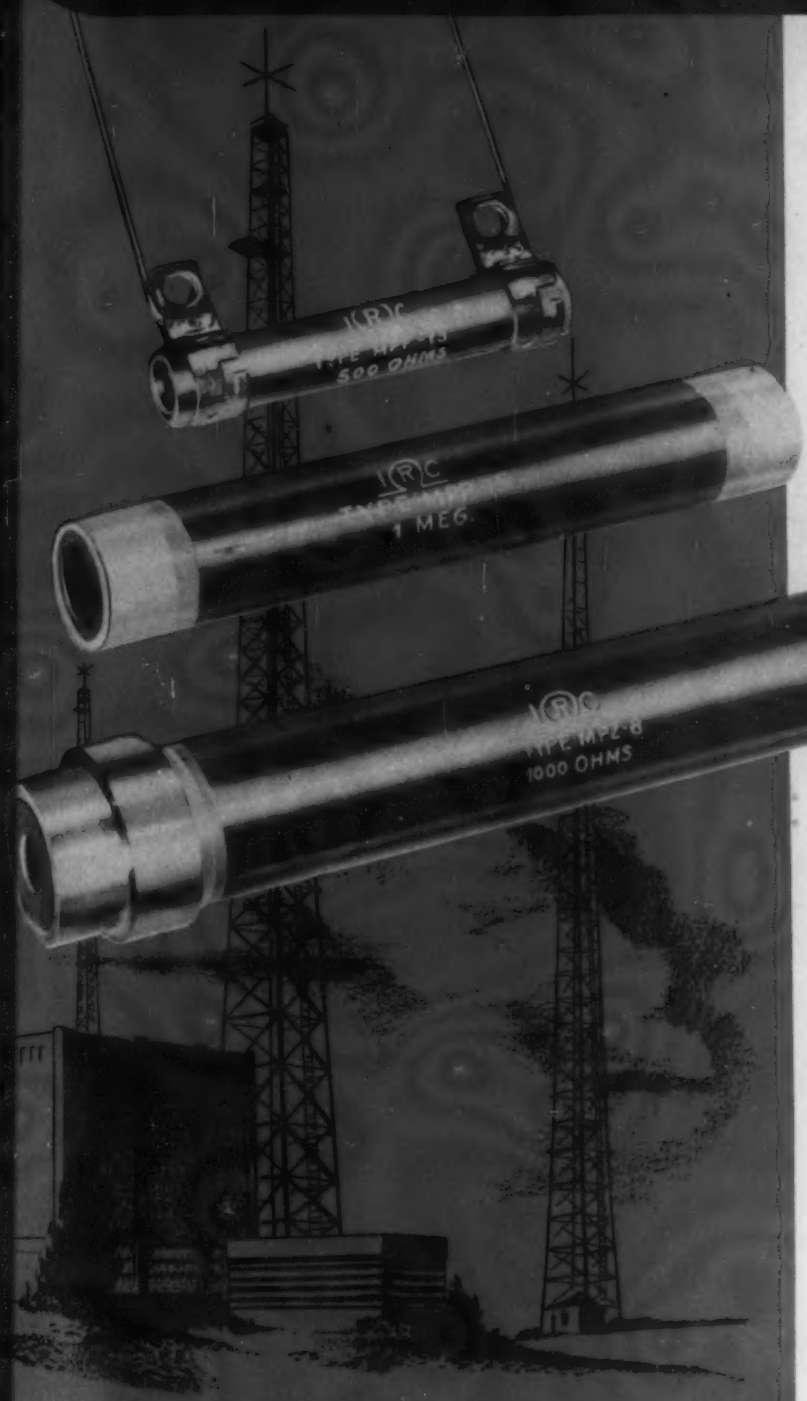
VOLTAGE COEFFICIENT OF RESISTANCE. Type MV Resistors have a voltage coefficient of resistance which varies from approximately —.002% to —.03% per volt per inch of length of resistance path.

TERMINALS. Terminal types all the same as those shown for MP resistors on page 15.

CATALOG DATA BULLETIN

Important information for Engineering and Purchasing Depts. Please file with your IRC Catalog.

INTERNATIONAL RESISTANCE CO., 401 N. Broad Street, Philadelphia 8, Pa., U.S.A.
IN CANADA: INTERNATIONAL RESISTANCE CO., LTD., TORONTO, LICENSEE



TYPE MP HIGH FREQUENCY RESISTORS

TYPE MP HIGH FREQUENCY RESISTORS

IRC Type MP Resistors are intended for frequencies above those of conventional resistors. They are suitable for such applications as broad band RF amplifiers, RF probes, rhombic antenna terminating resistors, dummy loads for transmitters and dielectric heating equipment, television side-band filters, surge generator and other circuits involving steep wave fronts, high frequency measuring circuits and radar pulse equipment. They are available in sizes from ¼ watt to 90 watts.

The IRC Type MP design utilizes the basic IRC technique of bonding a thin film of resistance material on a steatite ceramic form to provide a stable resistor with low inherent inductance and capacity.

The resistance film used on Type MP Resistors was developed especially for these units in order to obtain the best combination of mechanical stability and uniform electrical characteristics. Changes due to humidity and aging are held to a minimum. Voltage and temperature coefficients of resistance are low. The small cross-sectional area of the film (it is less than 0.001" thick) provides low inherent capacity and freedom from "skin effect". Inductance is materially reduced by the large ratio of diameter to length.

The steatite ceramic tubes used in Type MP Resistors are chosen for their mechanical uniformity and strength, and stability under temperature and humidity variations. They are non-hygroscopic and have excellent electrical characteristics.

Terminal bands of colloidal silver are applied at each end of the unit to provide permanent low resistance contact to the resistance coating. Lug or ferrule type terminals, if required, are secured over the silver end bands and a heavy protective coating is baked on the entire resistor.

SPECIFICATIONS — MP RESISTORS

TYPE	TERMINAL TYPE AND DRAWING NO.	POWER RATING	PEAK VOLTAGE RATING	MINIMUM AVAILABLE RESISTANCE AT ±10% OR ±15% TOLERANCE	MINIMUM AVAILABLE RESISTANCE AT ±5% TOLERANCE	MAXIMUM AVAILABLE RESISTANCE AT ±5%, ±10% OR ±15% TOLERANCE	DIMENSIONS: CERAMIC LENGTH	DIMENSIONS: RESISTOR BODY DIAMETER	DIMENSIONS: CERAMIC I. D.	DIMENSIONS: WIDTH OF COLLOIDAL SILVER BANDS (#5 TERMINALS, NO. 5
MPF-12	#12, Fig. 1	2 watts	500	20 ohms	100 ohms	1.5 megohms	1-3/4" ± 1/32"	5/16" ± 1/32"	3/16"	9/16" ± 1/16"
MPF-13	#13, Fig. 3									
MPG-13	#13, Fig. 3	4 watts	800	20 ohms	100 ohms	1.5 megohms	2" ± 1/32"	9/16" ± 1/32"	3/8"	9/16" ± 1/16"
MPG-15	#15, Fig. 5									
MPG-16	#16, Fig. 2									
MPG-17	#17, Fig. 4									
MPJ-15	#15, Fig. 5	5 watts	1000	35 ohms	200 ohms	3.0 megohms	3" ± 1/32"	9/16" ± 1/32"	3/8"	9/16" ± 1/16"
MPJ-16	#16, Fig. 2									
MPJ-17	#17, Fig. 4									
MPP-15	#15, Fig. 5	10 watts	1750	25 ohms	150 ohms	2.5 megohms	4-1/2" ± 1/16"	3/4" ± 1/32"	1/2"	9/16" ± 1/16"
MPP-16	#16, Fig. 2									
MPP-17	#17, Fig. 4									
MPA-15	#15, Fig. 5	20 watts	2750	35 ohms	250 ohms	4.0 megohms	6-1/2" ± 1/16"	1-1/8" ± 1/32"	3/4"	9/16" ± 1/16"
MPA-16	#16, Fig. 2									
MPA-17	#17, Fig. 4									
MPO-15	#15, Fig. 5	30 watts	4750	50 ohms	400 ohms	5.0 megohms	10-1/2" ± 1/16"	1-1/8" ± 1/32"	3/4"	9/16" ± 1/16"
MPO-16	#16, Fig. 2									
MPO-17	#17, Fig. 4									
MPR-15	#15, Fig. 5	90 watts	8500	60 ohms	500 ohms	6.0 megohms	18-1/2" ± 1/8"	2" ± 3/64"	1-9/16"	7/8" ± 1/16"
MPR-17	#17, Fig. 4									

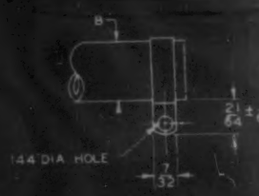


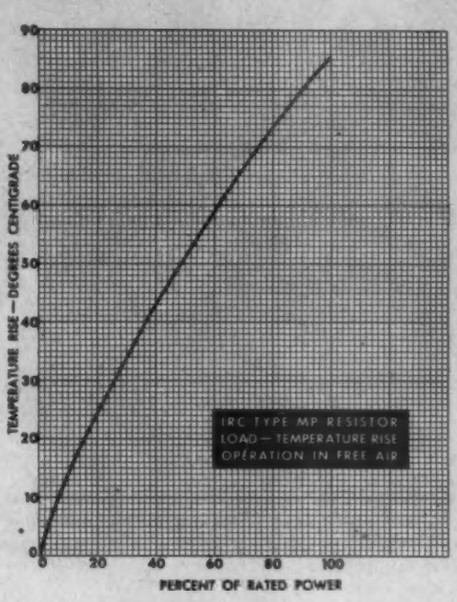
FIGURE 1

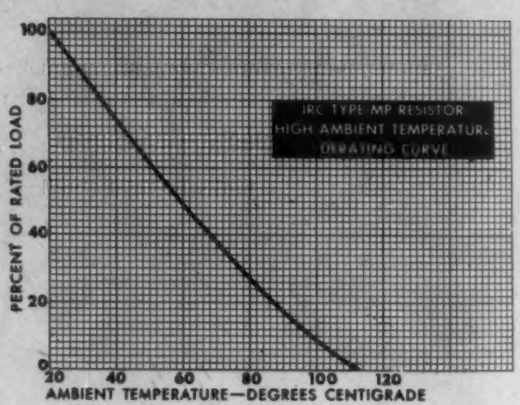
WITH LUG TERMINALS OR COLLOIDAL SILVER TERMINALS

WITH FERRULE TERMINALS, #5, #7, AND #8

CHARACTERISTICS — MP HIGH FREQUENCY RESISTORS

POWER RATINGS. The ratings shown in the above specification charts are based on free air operation at 20°C. ambient and should not be exceeded.





DERATING. Type MP Resistor power ratings are based on an ambient temperature of 20°C. When operated at any higher ambient, it is recommended that they be derated according to the following curve. For example, suppose an MPO Resistor is to be operated in an ambient temperature of 40°C. From the curve it is seen that the permissible load is 74% of the rated load. Since the MPO is normally rated at 30 watts, then at 40°C., it should not be loaded to more than 74% of 30 watts, or 22.2 watts.

TEMPERATURE COEFFICIENT. –.005% °C. for low resistance to –.07% °C. for high resistance value.

COOLING TO INCREASE POWER RATING. Various methods may be used for artificially removing heat from Type MP Resistors to increase their power capacity. In any cooling method, however, the maximum voltage rating and "hot spot" temperature (110°C. for short-time intermittent operation or 90°C. for continuous operation) must not be exceeded.

Safe power dissipation may be materially increased by cooling the units in a forced air draft. By efficient water cooling, safe operation at a power exceeding 100 times that for operation in air may be secured. (See IRC Catalog Bulletin F-2 pertaining to Type LP Water-Cooled Resistors up to 5 K.W.) Type MP units also can be furnished for operation in oil as a means of increasing power and voltage ratings.

When planning the use of any special cooling method for Type MP installations, it is advisable to furnish complete details of the specific application so that IRC engineers may recommend the proper units and installation methods.

TYPE MPM RESISTORS

FIGURE 2 FIGURE 3 FIGURE 4 FIGURE 5

TYPE	POWER RATING	PEAK VOLTAGE RATING	MINIMUM AVAILABLE RESISTANCE AT ±10% OR ±10% TOLERANCE	MINIMUM AVAILABLE RESISTANCE AT ±5% TOLERANCE	MAXIMUM AVAILABLE RESISTANCE AT ±5%, ±10% OR ±15% TOLERANCE	OUTLINE DRAWING	DIMENSIONS OVERALL LENGTH "A"	DIMENSIONS NOMINAL DIAMETER "B"	DIMENSIONS FERRULE SPACING "C"	DIMENSIONS FERRULE DIAMETER "D"	DIMENSIONS FERRULE LENGTH "E"
MPS-5	4.0 watts	500	10 ohms	75 ohms	1.0 megohm	Fig. 6	2-7/16" ± 1/8"	11/16" ± 1/32"	1-3/8" ± 1/16"	9/16" ± 1/32"	1/2" + 1/16-0"
MPT-5	5.0 watts	750	15 ohms	100 ohms	1.5 megohms	" "	3" ± 1/8"	11/16" ± 1/32"	1-15/16" ± 1/16"	9/16" ± 1/32"	1/2" + 1/16-0"
MPB-7	7.5 watts	1200	20 ohms	125 ohms	2.5 megohms	" "	4-1/2" ± 1/8"	1" ± 1/32"	3-7/16" ± 1/16"	13/16" ± 1/32"	1/2" + 1/16-0"
MPD-7	10.0 watts	1500	25 ohms	150 ohms	3.0 megohms	" "	5-3/16" ± 1/8"	1" ± 1/32"	4-1/8" ± 1/16"	13/16" ± 1/32"	1/2" + 1/16-0"
MPZ-8	20.0 watts	2750	35 ohms	250 ohms	4.0 megohms	" "	7-1/2" ± 1/8"	1-1/8" ± 1/32"	6-7/16" ± 1/16"	1-1/8" ± 1/32"	1/2" + 1/16-0"
MPE-8	25.0 watts	3800	40 ohms	300 ohms	4.5 megohms	" "	9-11/16" ± 1/8"	1-1/8" ± 1/32"	8-5/8" ± 1/16"	1-1/8" ± 1/32"	1/2" + 1/16-0"
MPO-7	30.0 watts	4750	50 ohms	400 ohms	5.0 megohms	" "	11-3/4" ± 1/8"	1-1/8" ± 1/32"	10-13/16" ± 1/16"	13/16" ± 1/32"	1/2" + 1/16-0"
MPR-8	90.0 watts	8300	60 ohms	500 ohms	6.0 megohms	" "	19-3/4" ± 3/16"	2" ± 3/64"	18-1/2" ± 5/32"	1-1/8" ± 1/32"	9/16" + 1/32-0"

* 5, 7 AND 8 TERMINALS

FIGURE 6

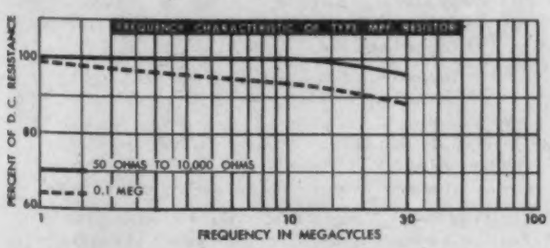
HUMIDITY. Several protective coatings of special varnish, baked individually at high temperature, provide protection against the effects of abnormal humidity. Maximum resistance change of ±5% can be expected due to humidity. Resistance will return to original value when humidity conditions become normal.

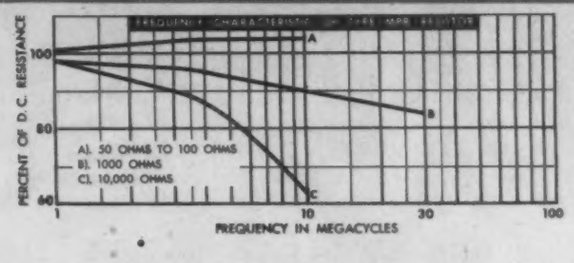
VOLTAGE COEFFICIENT OF RESISTANCE. Type MP Resistors have a voltage coefficient of resistance which varies from approximately −.002% to −.03% per volt per inch of length of resistance path. The active length of resistance path is given in the following table to facilitate the calculation of voltage coefficients.

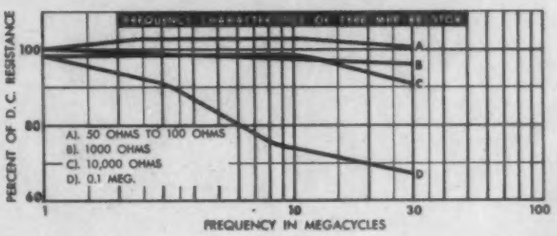
MP TYPE	LENGTH OF RESISTANCE PATH IN INCHES	MP TYPE	LENGTH OF RESISTANCE PATH IN INCHES
MPF	1.0	MPP	3.5
MPG	1.0	MPZ	5.25
MPS	1.0	MPA	5.5
MPT	1.5	MPE	7.5
MPJ	2.0	MPO	9.5
MPB	2.25	MPR	17.0
MPD	3.0		

AGING. Pre-curing and stabilizing of resistance coating at high temperature eliminates appreciable aging. Laboratory tests and field experience indicate that aging rarely exceeds ±3% of the original value.

FREQUENCY. Approximate frequency characteristics of typical MP units are illustrated by the following charts:







INSTALLATION

HANDLING. Type MP Resistors will stand ordinary handling; however, it is recommended that the units be installed after other mechanical work has been completed, and that the protective wrapping on the body of the resistor be left in place until the unit has been installed in the equipment.

MOUNTING. When Type MP Resistors are required to operate at elevated temperatures, they should be positioned so that free circulation of cool air can reach every part of the surface.

Where resistors are to be used near maximum allowable operating temperature they should be kept from close proximity to other parts radiating appreciable heat.

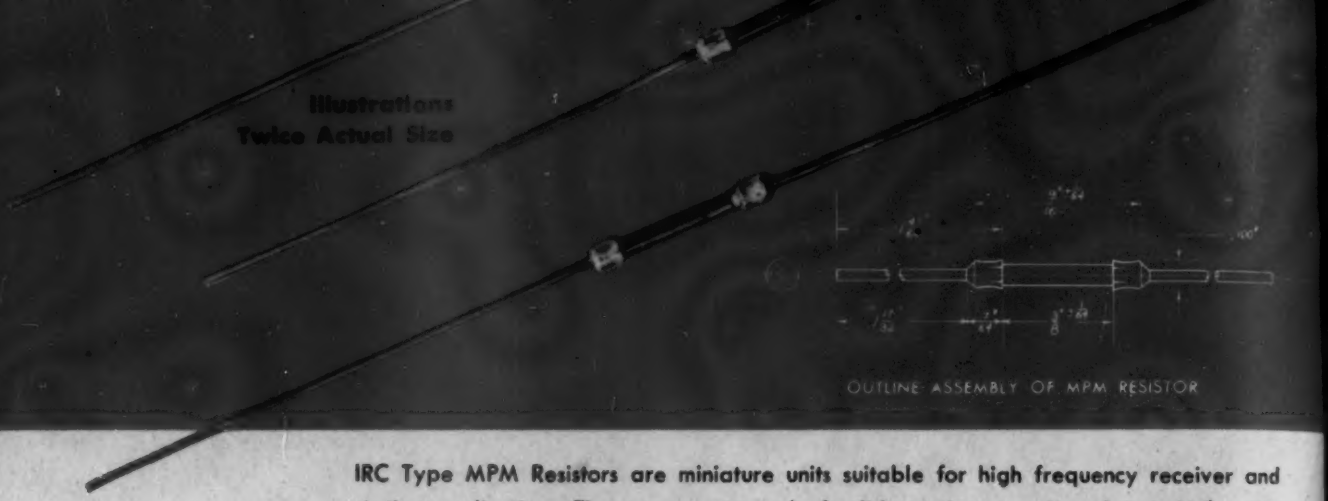
IRC

CATALOG DATA BULLETIN

Important information for Engineering and Purchasing Depts. Please file with your IRC Catalog.

INTERNATIONAL RESISTANCE CO., 401 N. Broad Street, Philadelphia 8, Pa., U.S.A.

IN CANADA, INTERNATIONAL RESISTANCE CO., LTD., TORONTO, LICENSEE



OUTLINE ASSEMBLY OF MPM RESISTOR

IRC Type MPM Resistors are miniature units suitable for high frequency receiver and similar applications. They are constructed of solid steatite ceramic rods to which a thin resistance film is permanently bonded. Wire lead terminals have "cupped" ends into which the resistor body is firmly cemented to form axial pigtails. The entire assembly is then coated with phenolic varnish. The electrical characteristics of these units are similar, except for frequency, to those of the larger type IRC MP Resistors. The approximate frequency characteristics for various ranges are shown below. Terminals are axial wire pigtails, 1½ inches long. Resistor body is 9/16" by 0.100" (over cups), and the active resistance section is 3/8" long.

AVAILABLE RESISTANCE VALUES:

30 ohms to 1.0 megohms.

RESISTANCE TOLERANCE:

Standard: ±20%; Special: ±10%. 5% not available.

POWER RATING:

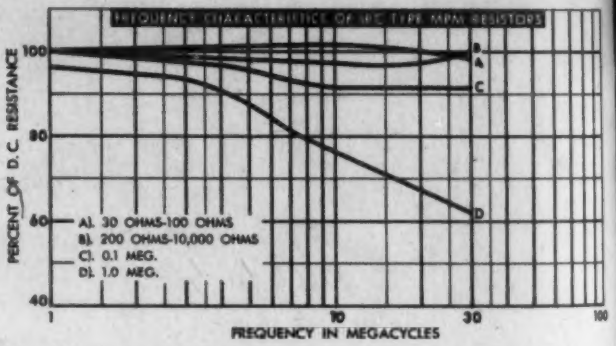
¼ watt, at 40°C. ambient temperature.

MAXIMUM VOLTAGE RATING:

200 volts peak.

CAPACITY BETWEEN TERMINALS:

0.015 Micro-microfarads.



TEMPERATURE COEFFICIENT OF RESISTANCE:

Approximately minus 0.04% per degree over temperature range of—55°C. to +80°C.

INTERNATIONAL RESISTANCE CO.

IRC

401 NORTH BROAD STREET
PHILADELPHIA 8, PA. U. S. A.
TELEPHONE: WA 3-2166

IN CANADA: INTERNATIONAL RESISTANCE CO., LTD.
11 KING STREET WEST, TORONTO, LICENSEE

BRANCH OFFICE: 165 BROADWAY, NEW YORK, N. Y., Courtland 7-5020

SALES REPRESENTATIVES:

Hollingsworth & Still
407 Harris Bldg.
ATLANTA, Ga.
Main 5870

Ray Perron & Co.
131 Clarendon St.
BOSTON, Mass.
Kenmore 1370

Sager & Taylor Co.
4508 E. Genesee St.
DE WITT, N. Y.

S. B. Darmstader
308 W. Washington St.
CHICAGO, Ill.
Franklin 4818

Albert M. Bashr
11621 Detroit Ave.
CLEVELAND, Ohio
Lakewood 8468

George E. Anderson Co.
1903 Griffin St.
DALLAS, Tex.
Riverside 1272

Ronald G. Bowen
1886 S. Humboldt St.
DENVER, Colo.
Spruce 9368

Koehler-Pasmore Co.
8316 Woodward Ave.
DETROIT, Mich.
Madison 8086

Vernon C. Macnabb
P. O. Box 5971
INDIANAPOLIS, Ind.
Broadway 6770

Marshank Sales Co.
672 S. Lafayette Park Place
LOS ANGELES, Calif.
Drexel 8235

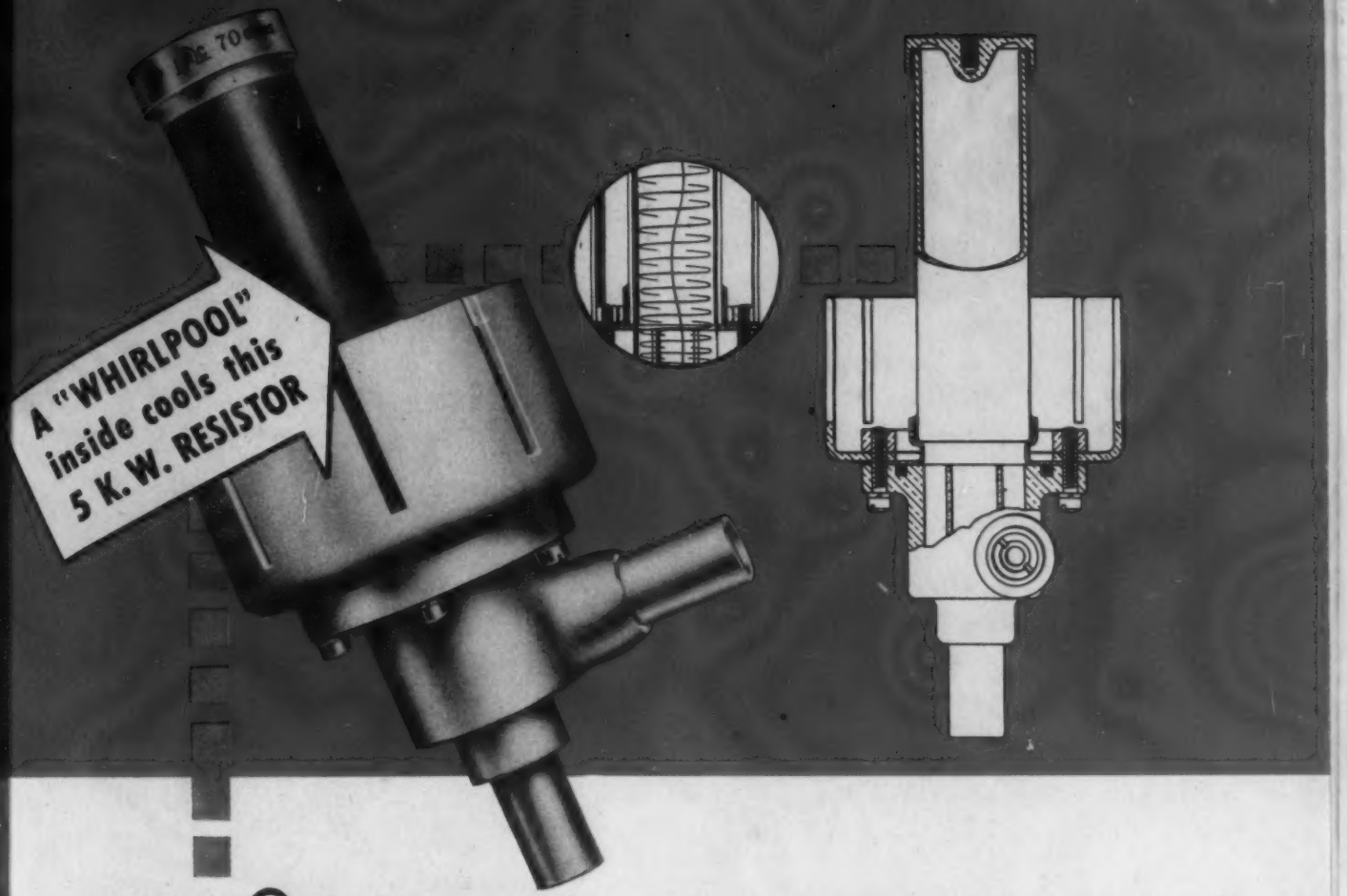
George C. Tanner
600 Grant St.
PITTSBURGH, Pa.
Court 0131

Norman W. Kathrinus
1218 Olive St.
ST. LOUIS, Mo.
Central 6300

J. U. McCarthy
1725 Hillcrest Ave.
ST. PAUL, Minn.
Emerson 8619

James P. Hermans Co.
1234 Folsom St.
SAN FRANCISCO, Calif.
Market 4166

David M. Lee
2626 Second Ave.
SEATTLE, Wash.
Main 5512



Unique IRC High Frequency-High Power Resistor for Television, FM, and Dielectric Heating Applications

Inside IRC's new Type LP resistor a high velocity stream of water flows in a spiral path against the *metallized* resistance film and, through centrifugal force, maintains intimate thermal contact with the entire surface. Interchangeable intake nozzles permit adjusting the rate of water flow and therefore the cooling action to suit local water pressure and power dissipation up to 5 K.W.

A resistance film less than 0.001" thick, with an active length considerably less than ¼ wave length at FM and television frequencies, gives good inherent frequency characteristics.

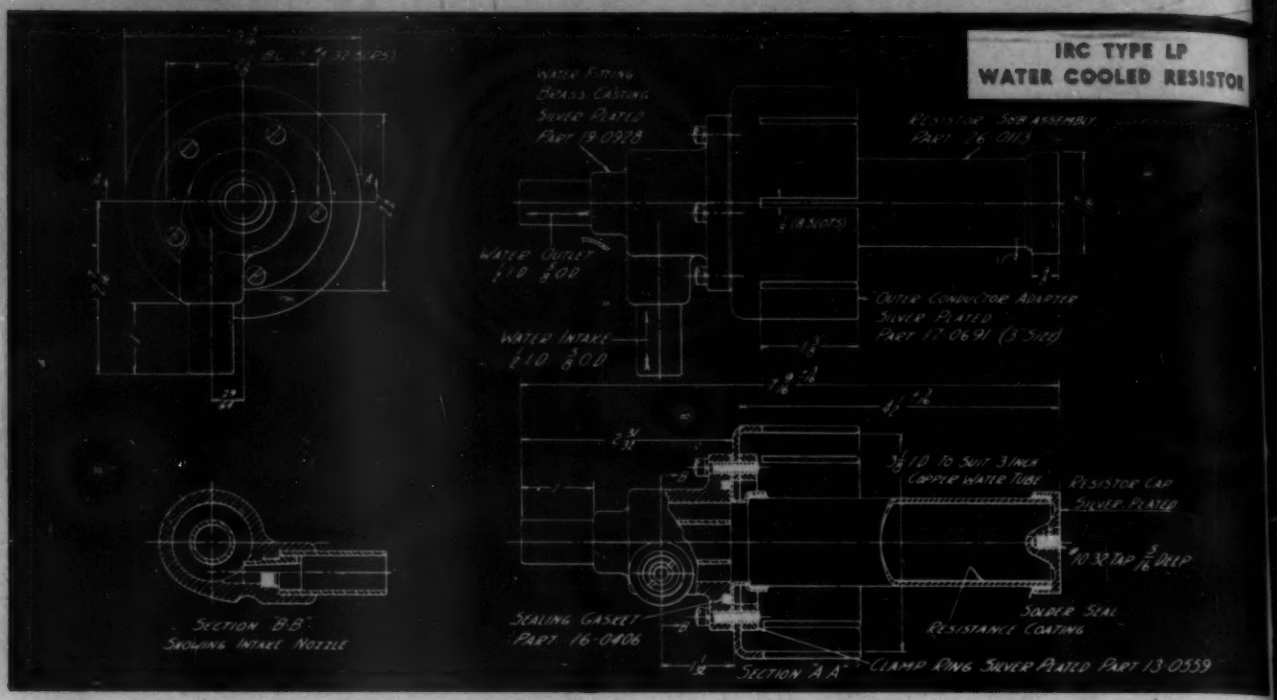
The mechanical design permits direct mounting on the end of a coaxial line with both water intake and outlet connections at R.F. ground potential. Resistor elements are interchangeable. Different values or service replacements can be readily installed in the field.

The IRC Type LP Liquid Cooled High Frequency High Power Unit is the latest in IRC's continuing development of resistors. It is available in resistance values of 35 ohms to 1500 ohms. Resistance tolerance: ±15% standard. Tolerances of ±10% and ±5% can be supplied at increased cost.

SHORT DELIVERY CYCLE

Fittings are now carried in stock. Resistance elements are made to order for range and tolerance.

INSTALLATION OF IRC TYPE LP WATER COOLED RESISTORS


IRC TYPE LP
WATER COOLED RESISTOR
WATER FITTING BRASS CASTING SILVER PLATED PART 13-0928
RESISTOR SUB ASSEMBLY PART 16-0113
WATER OUTLET
WATER INTAKE
OUTER CONDUCTOR ADAPTER SILVER PLATED PART 17-0691 (3 SIZE)
5/8 I.D. TO SUIT 3 INCH COPPER WATER TUBE
RESISTOR CAP SILVER PLATED
10-32 TAP
SOLDER SEAL RESISTANCE COATING
SECTION "BB" SHOWING INTAKE NOZZLE
SEALING GASKET PART 16-0406
SECTION "A A"
CLAMP RING SILVER PLATED PART 13-0559

WATER COOLING: The resistor film on the interior of the Pyrex tube is less than 0.001" thick and has negligible heat storage capacity. High water velocity and intimate thermal contact between the water and carbon over its entire surface are necessary for proper heat dissipation. Oil or even perspiration on the inside surface may prevent wetting, so it is recommended that the resistor film inside be inspected before final installation. Warm soapy water will clean the resistor without harm to the carbon coating. This resistor is not recommended for DC applications.

Abrasive grit, metal filings, or particles of solder in the water supply will score the resistor film due to the velocity and centrifugal force of the liquid. Supply lines should be carefully flushed out before installation of the resistor, and a filter installed, if ordinary tap water is used for cooling. Before power is applied to the resistor, water should be allowed to circulate through the unit for at least three minutes in order to thoroughly wet resistance element and clear out air bubbles.

The position of mounting the resistor does not affect its operation. It will work satisfactorily with either end up or on its side.

The 5/8" tubing at the side of the water fitting, with the nozzle installed, is the water intake. The outlet tubing is on the axis of the resistor.

An intake nozzle with the proper hole size must be installed to ensure velocity and volume flow for a given power dissipation. Our No. 4 nozzle, normally supplied, has a 0.203" hole diameter and passes approximately 4 gals. per minute with a water pressure differential between inlet and outlet of 22 lbs. per square inch. This flow will handle 5 kilowatts A.C. at normal water temperatures. For a power dissipation of 2 kilowatts, our No. 2 nozzle has a 0.156" hole and will pass approximately 2 gals. per minute at 16 lbs. pressure. For powers of 1,000 watts or less, our No. 1 nozzle with a 0.109" hole, will pass approximately 1 gal. per minute at 20 lbs. pressure. Care should be used when installing these nozzles to prevent burring the inside which would disturb the flow. If a circulatory water system is used, output water should be cooled to counteract temperature rise.

Suitable couplings for connection to the external water supply are manufactured by the Imperial Brass Company. Their part No. 62F-5/8" union is a straight coupling for connection to 5/8" O.D. copper tubing. Their part No. 68F-1/2" is a similar coupling for connection to 1/2" standard pipe thread.

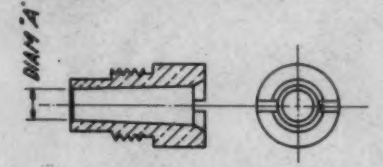
FITTING TO A COAXIAL LINE: Outer conductor adapter, see drawing No. B-17.0691, can be assembled in place under the clamp ring which holds the resistor flange. The resistor flange must always be assembled next to the water fitting with gasket, the outer conductor adapter next, and the clamp ring on top. This adapter is designed to clamp around the outside of a "three inch" coaxial line.

The inner conductor of the coaxial line is cut off 4 1/2" shorter than the outer conductor (the approximate length of the resistor unit sub-assembly) and assembled by an appropriate adapter to the cap on the end of the resistor.

Care must be taken in fitting the assembly to a line to insure that the inner and outer parts are lined up concentric, otherwise excessive strain may be placed on the glass tubing.

LP RESISTOR

NOZZLE	DIA "A"	WATER FLOW GAL. PER MIN	PRESSURE DIFF. INLET TO OUTLET	MAXIMUM POWER
1	0.109"	1	20# PER SQ IN.	1.0 KW.
2	0.156"	2	16 "	2.0 "
4	0.203"	4	22 "	5.0 "



INTERNATIONAL RESISTANCE CO.

401 NORTH BROAD STREET
PHILADELPHIA 8, PA., U. S. A.

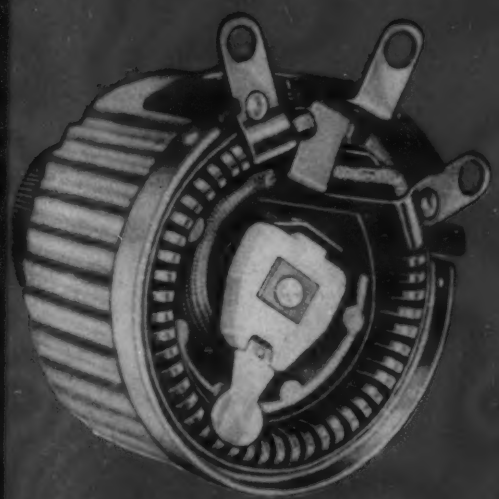
In Canada: INTERNATIONAL RESISTANCE CO., LTD.
11 KING STREET WEST, TORONTO 1, LICENSEE

CATALOG DATA BULLETIN

Important information for Engineering and Purchasing Depts. Please file with your IRC Catalog.
INTERNATIONAL RESISTANCE CO., 401 N. Broad St., Philadelphia 8, Pa., U. S. A.
In Canada: International Resistance Co., Ltd., Toronto, Licensee

POWER RHEOSTATS

TYPE PR-25 — FRONT VIEW
25 WATTS



TYPE PR-50 — REAR VIEW
50 WATTS

ALL-METAL CONSTRUCTION

The basis of the vast superiority of IRC PR 25 and PR 50 Power Rheostats over conventional types is a unique design featuring all-metal construction. The excellent heat dissipating properties of aluminum are utilized to full advantage in the housing and in the winding core of the resistance element of these IRC Rheostats.

PR 25 and PR 50 Rheostats operate at full rating at approximately half the temperature rise of equivalent units, and can be operated at full power in as low as 25% of rotation without any appreciable difference in temperature rise.

Through efficient use of the best grade mica and special asbestos, the insulation properties of these rheostats satisfactorily meet all service requirements. The heat dissipating and insulation features of IRC PR 25 will allow safe operation at 25 watts down to 25% of full rotation with a temperature rise of about 160°C., and for the PR 50, at 50 watts down to 25% of full rotation with a temperature rise of approximately 200°C.

HOUSING. Ribbed die cast aluminum alloy case designed to conduct heat away from resistance element. Since the external sides of the case are ribbed, it offers exceptionally efficient heat radiation. Intimate contact between rheostat and mounting panel allows rapid conduction to the panel of a portion of the heat dissipated.

RESISTANCE ELEMENT. Low temperature coefficient wire is uniformly wound on a strip aluminum core insulated by top grade asbestos. This insures uniform heat distribution throughout the entire resistance element regardless of how much of the element is actually in service.

Through the use of layers of best grade mica, the resistance element is insulated from the die cast housing. This construction allows more than sufficient insulation and at the same time, aids in conducting heat from the element to the housing.

CONTACT. Contact is made to the large radius edge of the resistance element by means of a special alloy which will neither pit nor stick. Close calibration and smooth variations in resistance are made possible over entire element. Pressure is provided by means of a separate steel spring, not in the current carrying path, thus separating the two functions of carrying current and applying pressure.

SPIRAL SPRING CONNECTOR. A flat clockspring, the famous IRC Spiral Spring Connector, is used to connect the sliding contactor to the center terminal. This eliminates the conventional series pressure contact, and insures long life and dependability.

MOUNTING. Single ⅜" hole mounting, bushing ½" long x ⅜" x 32 thread—brass. Other lengths available on special order.

SHAFT. Standard shaft nickel plated steel ¼" diameter. Length of shaft beyond bushing ½". Other lengths available as indicated on Page 2. Shaft is insulated, permitting mounting of rheostat on metal panel.

SHAFT ROTATION. PR 25 Rheostat — 290°
PR 50 Rheostat — 280°

LOCATING PIN. ⅛" diameter pin cast in base on 0.512" radius, as shown in diagram on Page 2.

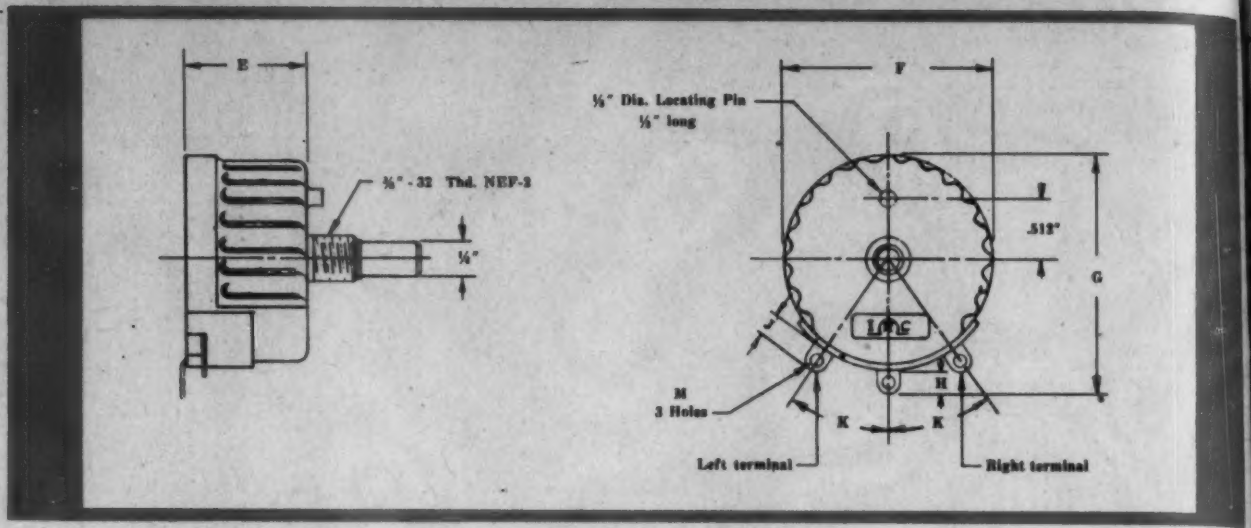
KNOB. Conventional type knob of molded bakelite is available on order.

COVER. Cover for protection against mechanical injury is available on order. Use of cover necessitates reduction of rating by ⅓ of standard.

OFF POSITION. Positive-action "off" position is standard.

SPECIFICATIONS

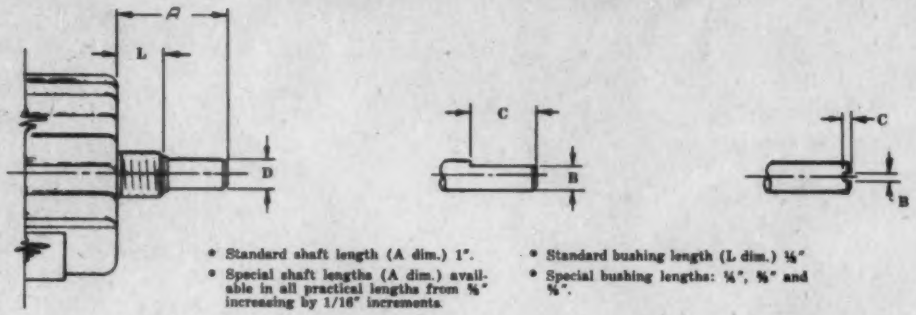
PR-25 AND PR-50 RHEOSTATS



DIMENSIONS

TYPE	E	F	G	H	J	K	M
PR-25	1"	$1\frac{21}{31}$"	$1\frac{15}{16}$"	$\frac{7}{32}$"	$\frac{5}{16}$"	35°	$\frac{5}{32}$" dia.
PR-50	$1\frac{13}{32}$"	$2\frac{3}{8}$"	$2\frac{15}{16}$"	½"	$\frac{7}{16}$"	40°	Clear #8 screw

STANDARD SHAFT TREATMENT



- Standard shaft length (A dim.) 1".
- Special shaft lengths (A dim.) available in all practical lengths from ¾" increasing by 1/16" increments.
- Standard bushing length (L dim.) ¼"
- Special bushing lengths: ¼", ⅜" and ½".

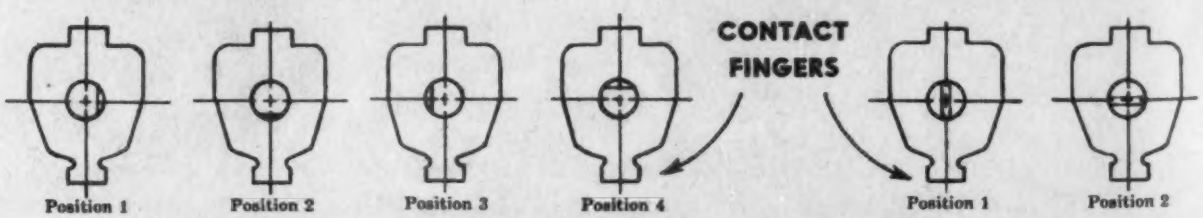
ROUND	
TYPE	DIM. D
1	.250 $^{+.000}_{-.002}$

FLAT		
TYPE	DIM. B	DIM. C
2	.216 ±.002	7/16"
3	.216 ±.002	⅜"
4	.216 ±.002	11/32"
5	.216 ±.002	5/16"
6	.216 ±.002	¼"

SLOT		
TYPE	DIM. B	DIM. C
7	.075"	1/16"
8	1/16"	1/16"
9	3/64"	1/16"

STANDARD FLAT POSITION

STANDARD SLOT POSITION



CHARACTERISTICS PR-25 AND PR-50 RHEOSTATS

TYPE PR-25
25 - WATT RHEOSTAT

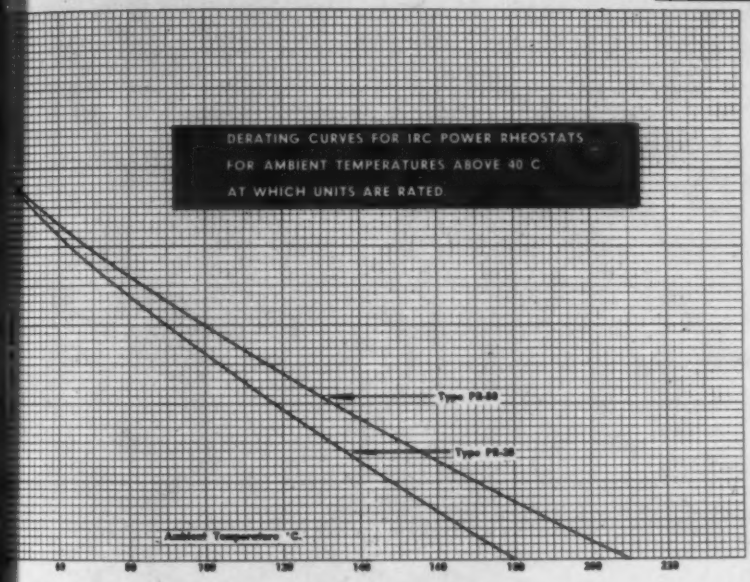
Total Ohms Resistance	* Max. Current Milliamps	Approx. Total Steps	Total Ohms Resistance	* Max. Current Milliamps	Approx. Total Steps
1	5,000	28	125	445	132
2	3,530	31	175	375	146
3	2,880	34	250	315	150
6	2,040	48	350	267	180
8	1,770	48	500	222	158
10	1,580	57	750	182	185
15	1,265	48	1,000	155	255
25	1,000	100	1,500	129	250
35	845	72	2,500	100	330
50	707	80	3,500	84	370
75	575	100	5,000	70	540
100	500	100			

* Max. current at full winding.
These are standard values available from IRC Distributors stocks. Intermediate values available on special order.

TYPE PR-50
50 - WATT RHEOSTAT

Total Ohms Resistance	* Max. Current Milliamps	Approx. Total Steps	Total Ohms Resistance	* Max. Current Milliamps	Approx. Total Steps
0.5	10,000	27	150	575	160
1	7,070	27	225	470	170
2	5,000	35	300	405	210
4	3,530	45	500	315	220
6	2,880	45	800	250	280
8	2,500	45	1,000	220	280
12	2,040	66	1,600	176	360
16	1,760	70	2,500	140	360
22	1,500	66	3,500	119	390
35	1,190	115	5,000	100	435
50	1,000	125	8,000	79	540
80	790	107	10,000	70	680
125	630	135			

* Max. current at full winding.
These are standard values available from IRC Distributors stocks. Intermediate values available on special order.


DERATING CURVES FOR IRC POWER RHEOSTATS
FOR AMBIENT TEMPERATURES ABOVE 40 C.
AT WHICH UNITS ARE RATED
Type PR-50
Type PR-25
Ambient Temperature °C.

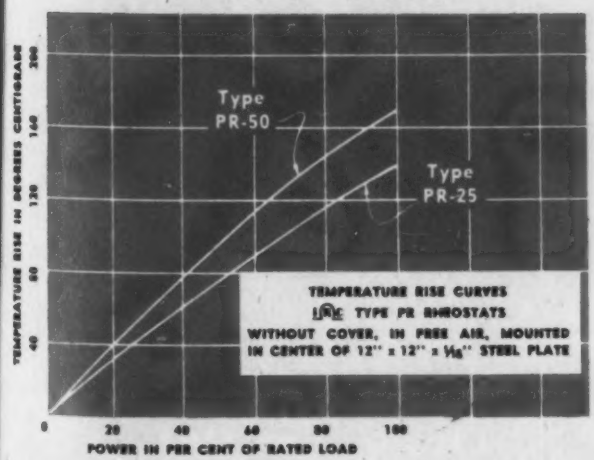
RESISTANCE VALUES. 1 ohm to 5,000 ohms for the PR 25 Rheostat, and 0.5 ohm to 10,000 ohms for the PR 50 Rheostat are standard.

TOLERANCE. ±10% is standard. ±5% available at extra cost on ranges above 10 ohms with linear taper.

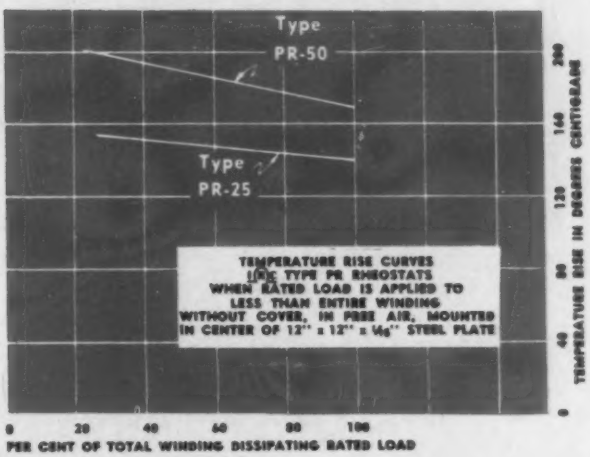
RATING. PR Rheostats are rated at 25 and 50 watts, based upon a 140°C temperature rise above a 40°C. ambient for PR 25, and 170°C. temperature rise above a 40°C. ambient for PR 50.

DERATING. If units are to be operated at an ambient higher than 40°C., they should be derated according to the Derating Curve on the last page. For example: A PR 50 Rheostat is to be operated at an ambient temperature of 80°C. From the Derating Curve it can be seen that only 73% of the 50 watt rating can be used, or 36.5 watts.

LOW TEMPERATURE RISE


Type PR-50
Type PR-25
TEMPERATURE RISE CURVES
IRC TYPE PR RHEOSTATS
WITHOUT COVER, IN FREE AIR, MOUNTED
IN CENTER OF 12" x 12" x 1/16" STEEL PLATE
TEMPERATURE RISE IN DEGREES CENTIGRADE
POWER IN PER CENT OF RATED LOAD

LOW TEMPERATURE OPERATION WITH FULL LOAD ON PART OF WINDING


Type PR-50
Type PR-25
TEMPERATURE RISE CURVES
IRC TYPE PR RHEOSTATS
WHEN RATED LOAD IS APPLIED TO
LESS THAN ENTIRE WINDING
WITHOUT COVER, IN FREE AIR, MOUNTED
IN CENTER OF 12" x 12" x 1/16" STEEL PLATE
TEMPERATURE RISE IN DEGREES CENTIGRADE
PER CENT OF TOTAL WINDING DISSIPATING RATED LOAD

SPECIFICATIONS

TYPE PRT (AN3155) POWER RHEOSTAT

IRC PART NUMBERS AND STANDARD AN3155 RESISTANCE RANGES

Order by IRC Part No.	Army-Navy Part No.	Nominal Watts Rating	Total Resistance Ohms	Amperes at		Type of Winding
				Min. Resist.	Max. Resist.	
PRT-25-10	AN3155-25-10	25	10	1.95	0.30	Tapered
-25-15	-25-15	25	15	1.30	1.30	Linear
-25-25	-25-25	25	25	1.00	1.00	Linear
-25-50	-25-50	25	50	0.71	0.71	Linear
-25-75	-25-75	25	75	0.58	0.58	Linear
-25-100	-25-100	25	100	0.85	0.16	Tapered
-25-200	-25-200	25	200	0.35	0.35	Linear
PRT-50-5	AN3155-50-5	50	5	5.50	1.82	Tapered
-50-8*	-50-8*	50	8	2.50	2.50	Linear*
-50-10	-50-10	50	10	2.50	1.60	Tapered
-50-25	-50-25	50	25	2.70	0.70	Tapered
-50-30*	-50-30*	50	30	1.70	0.90	Tapered*
-50-50	-50-50	50	50	1.00	1.00	Linear
-50-75	-50-75	50	75	0.82	0.82	Linear
-50-100	-50-100	50	100	1.35	0.25	Tapered
-50-150	-50-150	50	150	0.69	0.17	Tapered
-50-200	-50-200	50	200	1.35	0.15	Tapered

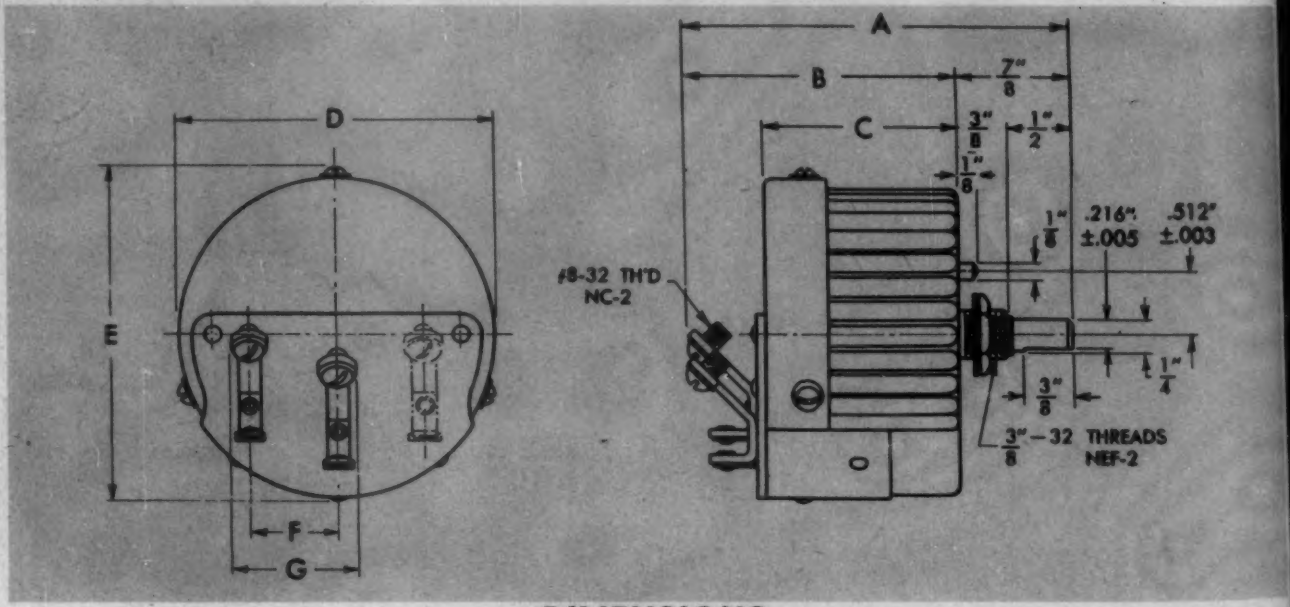
***On AN3155-50-8 and AN3155-50-30, rotation clockwise increases resistance, and minimum resistance is obtained when the rheostat is turned on from the "Off" position. On all other numbers maximum resistance is obtained when rheostat is turned on from "Off" position and rotation clockwise decreases resistance.**

VARIATIONS AVAILABLE

The Type PRT Rheostat has been standardized both mechanically and electrically, as required for U. S. Government aircraft applications. Full details are contained in Army-Navy Specifications AN-R-14a and Drawing AN3155. IRC Type PRT Rheostats are approved by the Air Technical Service Command and the Bureau of Aeronautics. PRT 25 and PRT 50 Rheostats are approved by the U. S. Signal Corps for types RP-11 and RP-16 respectively under JAN-R-22. When ordering against JAN-R-22 please give complete type designation. Variations in resistance values —to 5,000 ohms in the 25-watt Rheostat and to 10,000 ohms in the 50-watt type— are available on special order. For potentiometer applications, three terminals (left, right and center) can be supplied.

TOLERANCE

−5% +15% is standard.



DIMENSIONS

Type	A	B	C	D	E	F	G
PRT-25 (25-watt)	2-5/8"	1-3/4"	1-1/8"	1-23/32"	1-7/8"	13/32"	23/32"
PRT-50 (50-watt)	3-1/16"	2-3/16"	1-9/32"	2-7/16"	2-19/32"	11/16"	1"

CATALOG DATA BULLETIN

Important information for Engineering and Purchasing Depts. Please file with your IRC Catalog.

INTERNATIONAL RESISTANCE CO., 401 N. Broad St., Philadelphia 8, Pa., U. S. A.

In Canada: International Resistance Co., Ltd., Toronto, Licensee

IRC POWER WIRE WOUND RESISTORS

C Fixed and Adjustable Power Wire Wound Resistors are designed give *balanced* performance in *every* characteristic.

guard the windings against the harmful inroads of atmospheric isture and corrosion, all IRC power resistors are coated with a cial cement. The development of this particular coating was neered by IRC, and years of rigorous laboratory and field tests ve proven its superiority in the rapid dissipation of heat, ability withstand reasonable overloads without breakdowns or "opens," isture protection, immunity to salt water immersion and extreme chanical strength. The IRC cement coating contains no chem- lly active ingredients, no salts to attack the wire. The cement is ack-proof and cured and hardened at low temperature; thereby, t endangering the resistance windings.

nexcelled in essential electrical and mechanical characteristics, C Power Wire Wound Resistors are uniformly wound with the ighest grade alloy wire on tough, non-hygroscopic tubes, with gged terminals securely attached. They are available in a full nge of sizes, types and terminals.

r exacting, heavy-duty applications, high voltage bleeders, bias pply, grid, and filament dropping resistors, leading industrial, ircraft, broadcast, maritime and other commercial users have speci- ed IRC Power Wire Wound Resistors for over 14 years.

OATING SPECIFICATIONS. Because of the varied types of ser- ice power resistors must provide, IRC makes available two types of ament coatings. Each coating is designed to furnish maximum ependability at minimum cost for its class of service.

TYPE "B" COATING. The Type "B" Coating is designed for relatively low range high temperature requirements where wire size is large enough to insure dependability. The power ratings shown for Type "B" Coating are based on a temperature rise of 250° C. from a 25° C. ambient in free air. This coating is well suited for all wire sizes and normal humidity conditions.

TYPE "C" COATING. The Type "C" Coating is a specially developed organic cement coat designed to withstand the most extreme atmospheric conditions . . . such as on ships, in tropical countries, and in extremely humid climates. Power ratings shown for Type "C" Coating are based on a temperature rise of 130° C. above an ambient of 25° C. in free air. At no time should the total temperature (ambient plus rise) exceed 155° C.

TEST CYCLE FOR TYPE "C" COATING. The Type "C" Coating will withstand nine cycles of the following severe test when protecting wire of a diameter of .0025" or larger, on any size ceramic:

1. Operation at maximum rated temperature for six hours . . .
2. Immediate immersion in saturated solution of sodium chloride for two hours at 100° C. . . .
3. Immediate transference to zero degree saturated solution of sodium chloride and immersion for two hours . . .
4. Washed in clear water, wiped clean and operated on D.C. potential at maximum rated temperature for two hours.

SPECIFICATIONS POWER WIRE WOUND RESISTORS

STANDARD STOCK SIZES

These standard sizes are available from IRC distributors' stocks

IRC TYPE	Former Designation	Corresponding JAN Type	Wattage "B" Coat 250°C. Rise	Wattage "C" Coat 130°C. Rise	Ceramic Length	O. D.	I. D.	Minimum Possible Ohms	Minimum Recom'd. Ohms	Max. Ohms Using .0025 Wire	Max. Ohms Using .0014 Wire
1" A	—		5	2	1"	5/16"	3/16"	.05	.50	450	4,000
1¾" A*	AB		10	4	1¾"	5/16"	3/16"	.10	.30	1,250	12,000
2" D*	DG		20	8	2"	9/16"	⅜"	.10	.40	2,750	24,200
3½" E*	EN		40	16	3½"	¾"	½"	.10	.80	9,500	77,500
4½" E*	EP		50	20	4½"	¾"	½"	.10	1.0	13,000	108,000
6½" E*	ES		75	30	6½"	¾"	½"	.50	1.5	21,000	169,000
6½" H*	HA		100	40	6½"	1⅛"	¾"	.10	2.0	30,000	254,000
8½" H*	HE		150	60	8½"	1⅛"	¾"	.15	2.5	41,000	342,000
10½" H*	HO		200	80	10½"	1⅛"	¾"	.20	3.0	53,000	436,000

NON-STANDARD SIZES

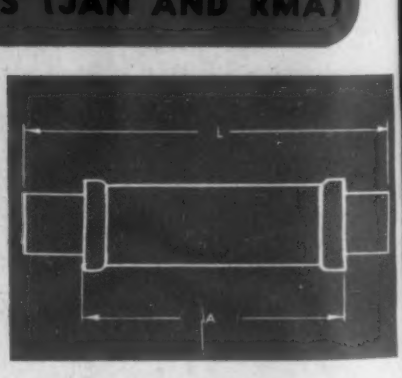
These non-standard sizes are manufactured to order

1" C	CA	RW-30	7	2.8	1"	7/16"	¼"	.10	.50	400	3,320
1½" C	CB	RW-31	10	4	1½"	7/16"	¼"	.10	.20	1,200	9,950
2" C	CG	RW-32	15	4	2"	7/16"	¼"	.10	.30	2,250	18,800
3" C	CJ	RW-33	18	5	3"	7/16"	¼"	.10	.50	4,250	36,600
2½" D*	DH		25	10	2½"	9/16"	⅜"	.10	.50	4,250	35,600
3" D*	DJ		30	12	3"	9/16"	⅜"	.10	.50	5,500	47,000
4" D*	DD		35	15	4"	9/16"	⅜"	.10	.50	8,500	70,000
5" D*	DK		45	18	5"	9/16"	⅜"	.10	.50	11,250	93,000
3" E*	ET	RW-34 RW-40	35	14	3"	¾"	½"	.10	.50	7,500	62,500
4" E*	ED	RW-35 RW-41	45	18	4"	¾"	½"	.10	.75	11,000	93,000
5" E*	ER		60	24	5"	¾"	½"	.10	.70	15,000	123,000
4" H*	HD	RW-36 RW-42	60	16	4"	1⅛"	¾"	.10	1.5	17,000	140,000
6" H*	HR	RW-37 RW-43	90	22	6"	1⅛"	¾"	.10	1.8	28,000	231,000
8" H*	HS	RW-38 RW-44	110	30	8"	1⅛"	¾"	.15	.50	39,000	323,000
12" H*	HT	RW-39 RW-45	225	90	12"	1⅛"	¾"	.25	3.0	61,000	505,000

* These sizes available with Adjustable Feature — see page 6 for additional information on adjustable power resistors and contact band. Add suffix "A" to type designation when specifying adjustable power wire wound resistors.
It is recommended that standard stock sizes be used wherever practicable.
See page 5 for Terminal Types available.

STANDARD FERRULE TYPE POWER RESISTORS (JAN AND RMA)

STYLE	WATTS "B" Coat	WATTS "C" Coat	Maximum Overall Length "L" Dimension	"A" Dimension ± 1/16"	Maximum Shoulder Diameter*	Maximum Ohms .0025" Wire	Fits Form #1 Standard Fuse Clip	Ferrule Terminal Number **
RW-10	140	37	11⅝"	10-7/16"	1-13/32"	63,000	60 A. 600 V.	8
RW-11	116	33	9-13/16"	8⅝"	1-13/32"	63,000	60 A. 600 V.	8
RW-12	86	23	7⅝"	6-7/16"	1-13/32"	50,000	60 A. 600 V.	8
RW-13	50	13	5-5/16"	4⅛"	1-3/32"	25,000	30 A. 600 V. 40 A. 250 V.	7
RW-14	40	12	4⅝"	3-7/16"	1-3/32"	16,000	30 A. 600 V. 60 A. 250 V.	7
RW-15	20	6	3⅛"	1-15/16"	27/32"	6,300	30 A. 250 V.	5
RW-16	14	4	2-9/16"	1⅜"	27/32"	4,000	30 A. 250 V.	5



* Body diameter always less than shoulder diameter.
** See page 25 for Ferrule details.

WINDING FORMS. Highest grade, non-hygroscopic ceramic winding form, chosen for mechanical strength, resistance to thermal shock and freedom from moisture absorption.

WIRE. Copper-nickel and nickel-chrome-iron alloys, largest sizes compatible with adequate spacing, wound with uniform spacing and tension.

INSULATION. 3000 volts A.C., R.M.S., between terminals and bracket.

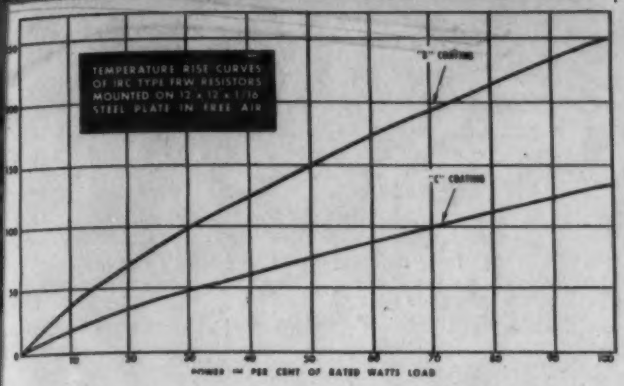
TERMINALS. Securely clamped around the ceramic winding form by spot welding; heavily tin dipped for easy soldering. Terminal types and specifications are given on page 25

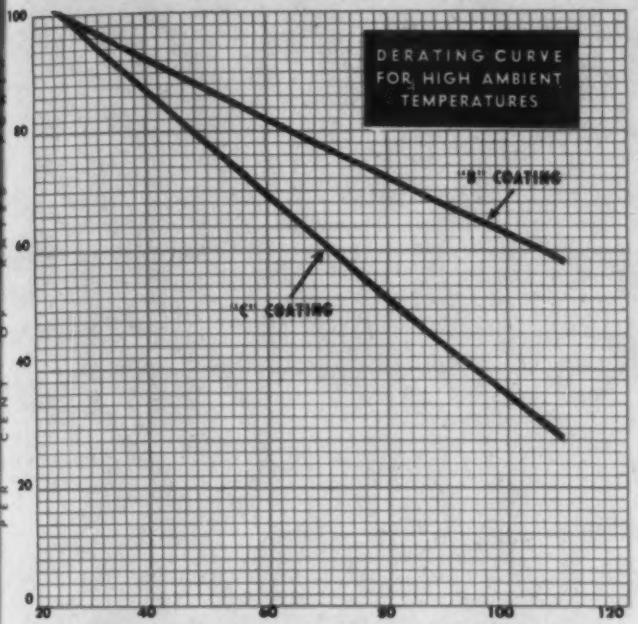
BRACKETS. Sturdy metal brackets, so designed that resistors are readily mounted by rivets or screws. Bracket holes will clear No. 10 machine screw. Specifications are given on page 25

MARKINGS. Permanently marked with type number and resistance.

MECHANICAL STRENGTH. Will withstand a transverse load in excess of 25 pounds without mechanical or electrical damage.

CHARACTERISTICS TYPE FRW POWER WIRE WOUND RESISTORS





POWER RATINGS. Based on standards of the AIEE and NEMA — 250° C. temperature rise at hottest external spot when suspended in free air for the "B" Coat; this is reduced for the "C" Coat to 40% of rating and 130° C. temperature rise. Maximum protection against moisture is provided with organic materials. Actual wattage load versus size of resistor used should take into consideration maximum ambient expected, ventilation, proximity of other parts susceptible to excessive temperatures, as well as temperature limitation of coating used.

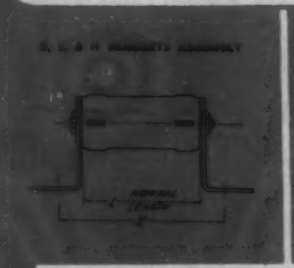
DERATING. If necessary to operate IRC Power Resistors in an ambient higher than 25° C., it is recommended that they be derated according to the Derating Curve for High Ambient Temperatures.

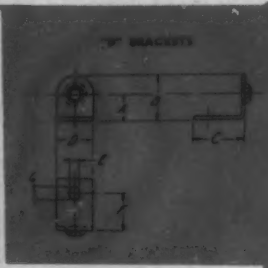
TAPS. Tapped resistors may be supplied within the limitation of the resistor size used. The use of a tap results in a small reduction of the power rating and ohmage available, since winding space is lost.

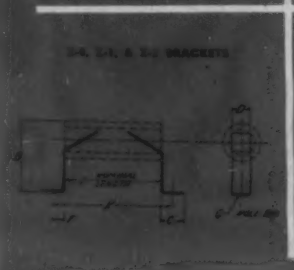
TOLERANCES. Standard tolerance 5% over 50 ohms. 10% below 50 ohms. Tolerances as low as 1.0% can be supplied at increased cost. The following table shows the minimum resistance value in which the various tolerances can be furnished for standard units. Minimum resistance value for non-standard units will be given upon request

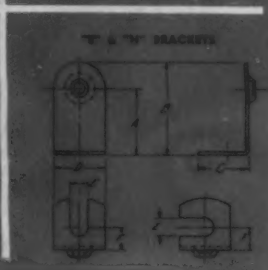
TYPE	1%	2%	3%	5%
1" A	——	3500 Ohms	1250 Ohms	50 Ohms
1⅜" A	250 Ohms	25	11	2
2" D	300	25	9	3
3½" E	100	12	2	.30
4½" E	40	8	.75	.40
6½" E	45	6	.60	.20
6½" H	30	10	2	.50
8½" H	18	10	2	.50
10½" H	12	1	.50	.20

BRACKET TYPES POWER WIRE WOUND RESISTORS





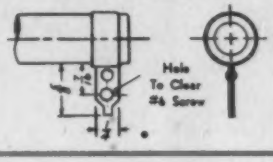




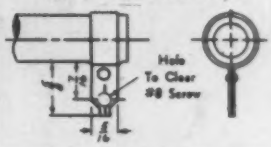
Bracket Type	Used With Resistor Type	Used With Resistor Dia.	A	B	C	D	E	F	G	Mounting Hole Centers
D	D	9/16	7/16	⅜	⅜	⅜	.144	⅜	.218	K = L + 1-5/16
E	E	⅝	1½	1-9/16	⅝	⅝	9/32	⅝		K = L + 13/16
H	H	1⅛	1½	2-1/16	1	1⅛	⅜	½		K = L + 1-1/16
Z-0	A	5/16		⅜	½	5/16		½	.173	K = L + ⅜ to ½
Z-1	D	9/16	*	1⅜	½	5/16		½	.173	K = L + ½
Z-2	E	⅝		1½	½	⅜		½	.173	K = L + ½

TERMINAL TYPES POWER WIRE WOUND RESISTORS

TYPE 3 — MOUNTING LUGS

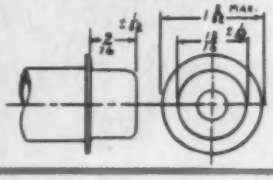


TYPE 4 — MOUNTING LUGS

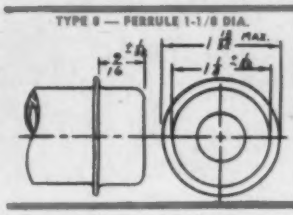


TYPE 5 — FERRULE 5/8 DIA.

TYPE 7 — FERRULE 13/16 DIA.

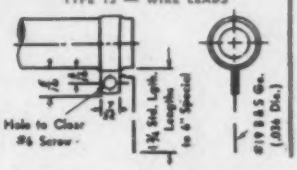


TYPE 8 — FERRULE 1-1/8 DIA.

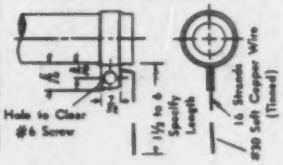


TYPE 12 — SOLDERING LUGS

TYPE 13 — WIRE LEADS



TYPE 14 — FLEXIBLE LEADS



TERMINAL NUMBER	CERAMIC TYPE A (1-16" O.D.)	C (7/16" O.D.)	D (7/16" O.D.)	E (⅝" O.D.)	H (1⅛" O.D.)	FERRULE TYPES ONLY		TERMINAL MATERIALS
3	X	ⓧ	X	ⓧ	X			Brass
4	X	X	X	X	ⓧ			Brass
5							FW-11 FW-13	Monel
7			X			FW-13 FW-14		Monel
8					FW-18, 11, 12			Monel
12	X		X					Phosphor-Bronze
13	ⓧ		ⓧ					Phosphor-Bronze Leg + Copper Pigtail
14	X		X					Phosphor-Bronze Leg + Stranded Copper Lead

ON ADJUSTABLE RESISTORS #12 TERMINAL IS STANDARD FOR TYPES "A" AND "B" CERAMICS

ADJUSTABLE POWER RESISTORS

The IRC Adjustable Power Wire Wound Resistor consists of a standard tubular resistor with a track of exposed wire. Contact is kept with the wire by means of a metal band which, when power is turned off, can be adjusted to any position along the resistor.

The adjustable band, designated as IRC Type "X," features a stainless steel spring with a silver contact button. Constant pressure is provided regardless of temperature because the steel spring is tempered for temperatures above resistor operating temperatures. The silver button, being oxidation free, cannot corrode to cause open circuits or high resistance at point of contact.

Type "X" Adjustable Bands are furnished for "D," "E" and "H" size ceramics; size "A" ceramics, because of their small size, are furnished with an adjustable band specially suited for smaller size units.

By the use of more than one band, various taps can be brought out and the unit used as a voltage divider. Additional adjustable bands can be furnished separately.

Since, on adjustable units, the resistance wire cannot be completely covered for protection against humidity, care should be taken not to use high resistance values requiring the use of extremely small wire sizes. The following table shows the adjustable types available, with their minimum and maximum resistance values. Additional information pertaining to IRC Adjustable Power Wire Wounds is given in the specification table on page 2.

	STANDARD SIZES												
	IRC TYPE	Former Designation	MINIMUM OHMS Recom.	MINIMUM OHMS Available	MAXIMUM OHMS Recom. .025 Wire	MAXIMUM OHMS Available .014 Wire	IRC TYPE	Former Designation	MINIMUM OHMS Recom.	MINIMUM OHMS Available	MAXIMUM OHMS Recom. .025 Wire	MAXIMUM OHMS Available .014 Wire
These standard sizes are carried in distributors' stocks	1¾" AA	ABA	.50	.10	1,700	7,500	6½" HA	HAA	7.	2.	50,000	160,000
	2" DA	DGA	1.	.20	3,750	15,250	8½" HA	HEA	8.	2.	70,000	200,000
	3½" EA	ENA	3.	.50	15,000	49,000	10½" HA	HOA	10.	3.	90,000	275,000
	4½" EA	EPA	3.	.60	21,000	68,000						
	6½" EA	ESA	4.	1.	32,500	100,000						
	NON-STANDARD SIZES											
These non-standard sizes are to be ordered in quantity	2½" DA	DHA	2.	.20	6,250	22,000	5" EA	ERA	4.	.70	24,000	78,000
	3" DA	DJA	2.	.30	8,750	30,000	4" HA	HDA	4.	1.	26,000	89,000
	4" DA	DDA	3.	.40	14,000	44,500	6" HA	HRA	7.	2.	46,000	145,000
	5" DA	DKA	3.	.60	18,000	58,000	8" HA	HSA	9.	3.	72,500	200,000
	3" EA	ETA	2.	.40	11,500	39,000	12" HA	HTA	14.	4.	100,000	300,000
	4" EA	EDA	3.	.50	17,500	58,000						

NON-INDUCTIVE POWER RESISTORS

IRC Non-Inductive Power Wire Wound Resistors utilize the Ayrton-Perry type winding which consists of two windings in parallel, wound in a single layer, in opposite directions. The turns of these windings touch at fixed points which are at the same potential and so eliminate capacitance effects. The power ratings are the same as those of standard inductive units.

The degree to which the inductance of these resistors is reduced is illustrated in the following table which shows the inductance of various size standard resistors as compared with that of the same size resistors wound with the Ayrton-Perry type winding.

TYPE RESISTOR	RESISTANCE OHMS	STANDARD WINDING INDUCTANCE MICRO-HENRIES	AYRTON-PERRY WINDING INDUCTANCE MICRO-HENRIES
1¾" A			
2" D	100	14	0.25
4½" E	80	76	0.3
6½" H	4,000	3,360	0.3

MAXIMUM RESISTANCE VALUES FOR SOME NON-INDUCTIVE TYPES	
TYPE	MAXIMUM RESISTANCE
1¾" NA	500 OHMS
2" ND	1,150 OHMS
4½" NE	5,000 OHMS
6½" NH	12,500 OHMS
10½" NH	22,000 OHMS

Since the Ayrton-Perry type winding consists of two windings and allowance must be made for suitable insulation between turns, it is impossible to wind the maximum resistance values given for standard resistors. The above table gives the maximum resistance values obtainable for some of the non-inductive types.

Non-inductive resistors are available in any of the standard Power Wire Wound sizes shown on page 2. The addition of the prefix letter N in front of the designation of a standard resistor is the designation of the non-inductive feature (4½" NE is a non-inductive 50 watt resistor).

INTERNATIONAL RESISTANCE CO.

401 NORTH BROAD STREET
PHILADELPHIA 8, PA. U. S. A.
TELEPHONE: WA 2-2166

IN CANADA: INTERNATIONAL RESISTANCE CO., LTD.
11 KING STREET WEST, TORONTO, LICENSEE

BRANCH OFFICE: 143 BROADWAY, NEW YORK, N. Y., Courtland 7-3070

SALES REPRESENTATIVES:

Hollingsworth & Stitt
407 Norris Bldg.
ATLANTA, Ga.
Main 5879

Ray Perron & Co.
131 Clarendon St.
BOSTON, Mass.
Kenmore 1370

Segar & Taylor Co.
4500 E. Genesee St.
DE WITT, N. Y.

S. D. Darmstader
308 W. Washington St.
CHICAGO, Ill.
Franklin 4618

Albert M. Boehr
11621 Detroit Ave.
CLEVELAND, Ohio
Lakewood 8468

George E. Anderson Co.
1903 Griffin St.
DALLAS, Tex.
Riverside 1272

Ronald G. Evans
1886 S. Humboldt St.
DENVER, Colo.
Spruce 9368

Koehler-Passmore Co.
8316 Woodward Ave.
DETROIT, Mich.
Madison 2066

Vernon C. Macomber
P. O. Box 5971
INDIANAPOLIS, Ind.
Broadway 6776

Marchand Sales Co.
672 S. Lafayette Park Place
LOS ANGELES, Calif.
Drexel 8235

George C. Tanner
600 Grant St.
PITTSBURGH, Pa.
Court 0131

Norman W. Rathbun
1218 Olive St.
ST. LOUIS, Mo.
Central 6300

J. U. McCarthy
1725 Hillcrest Ave.
ST. PAUL, Minn.
Emerson 0610

James P. Hermann Co.
1334 Folsom St.
SAN FRANCISCO, Calif.
Market 4146

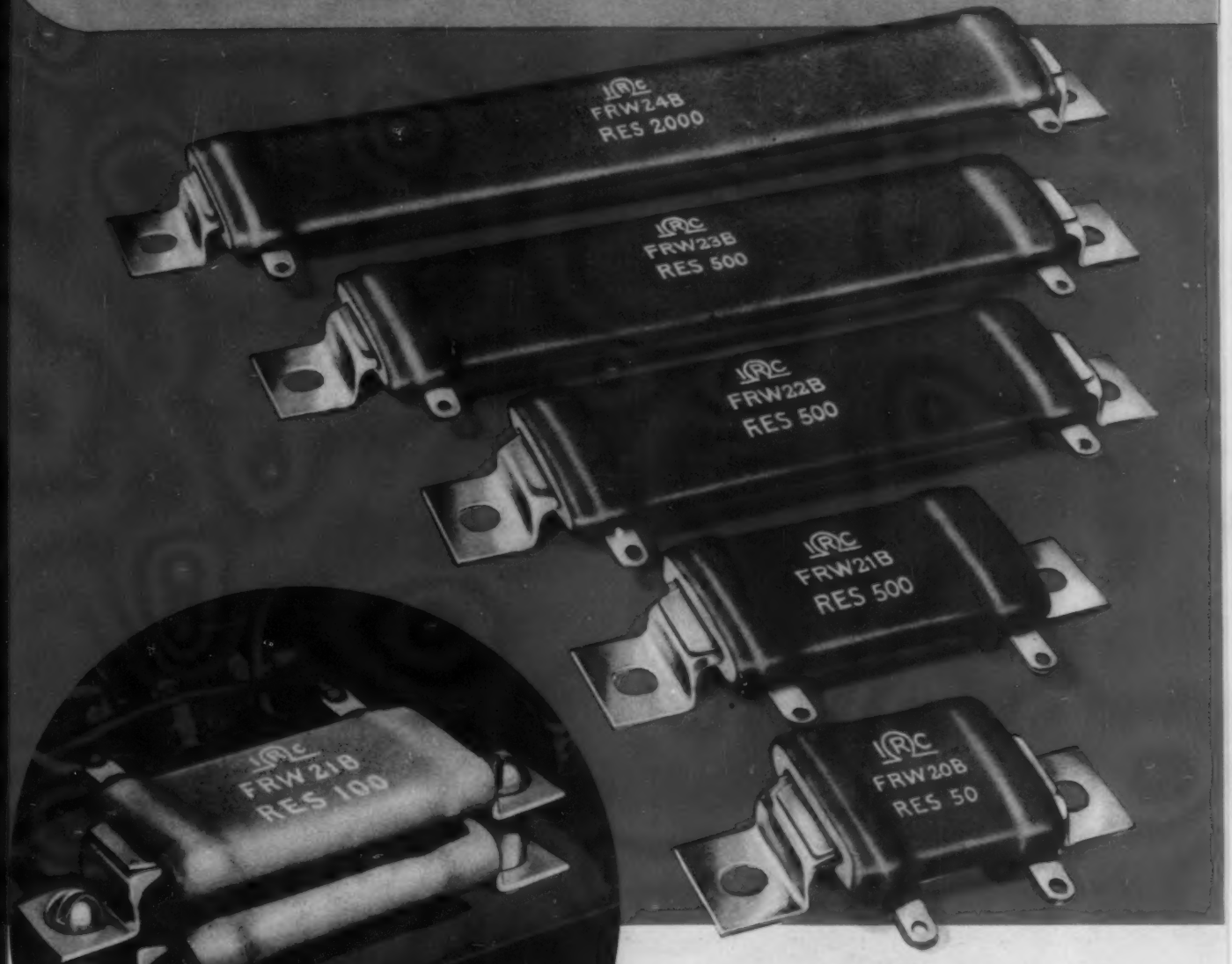
David M. Lee
2626 Second Ave.
SEATTLE, Wash.
Main 3512

CATALOG DATA BULLETIN

Important information for Engineering and Purchasing Depts. Please file with your IRC Catalog.

INTERNATIONAL RESISTANCE CO., 401 N. Broad St., Philadelphia 8, Pa., U. S. A.

In Canada: International Resistance Co., Ltd., Toronto, Licensee



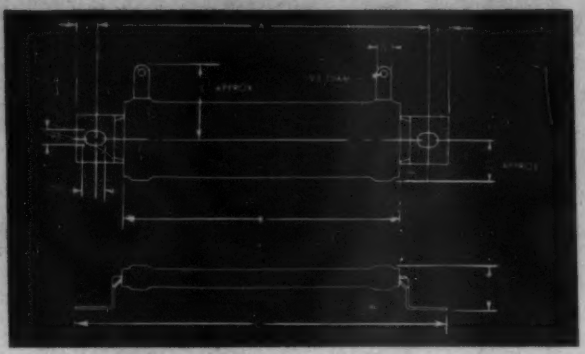
TYPE FRW
FLAT
WIRE WOUND RESISTORS

Designed to fulfill requirements of high wattage dissipation in limited-space applications, the IRC Type FRW Flat Wire Wound Resistor has a higher space-power ratio than standard tubular wire wounds. For different operating conditions, IRC makes these compact resistors available in two coatings, the IRC "B Coat" or "C Coat."

The Type FRW is designed for vertical or horizontal mounting, either singly or in stacks. Non-magnetic mounting brackets extending through the resistor allow easy and economical mounting, aid in heat distribution along its entire length and serve as conductors to transfer internal heat to the chassis.

Other features of the Type FRW are light-weight construction, combined with exceptional mechanical strength; and the ability to withstand severe vibration. In every detail, Type FRW Flat Wire Wound Resistors reflect IRC's traditional standards of high quality.

SPECIFICATIONS TYPE FRW POWER WIRE WOUND RESISTORS

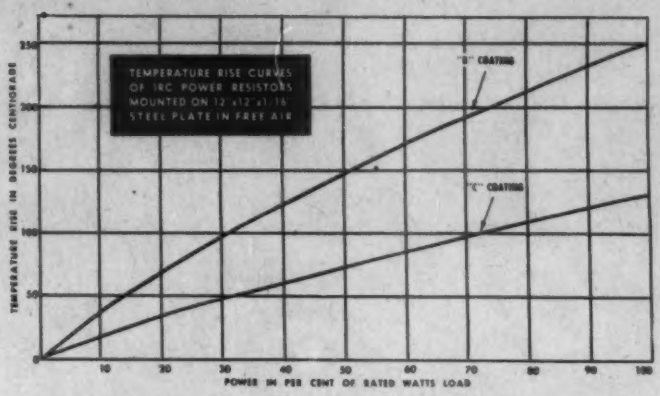


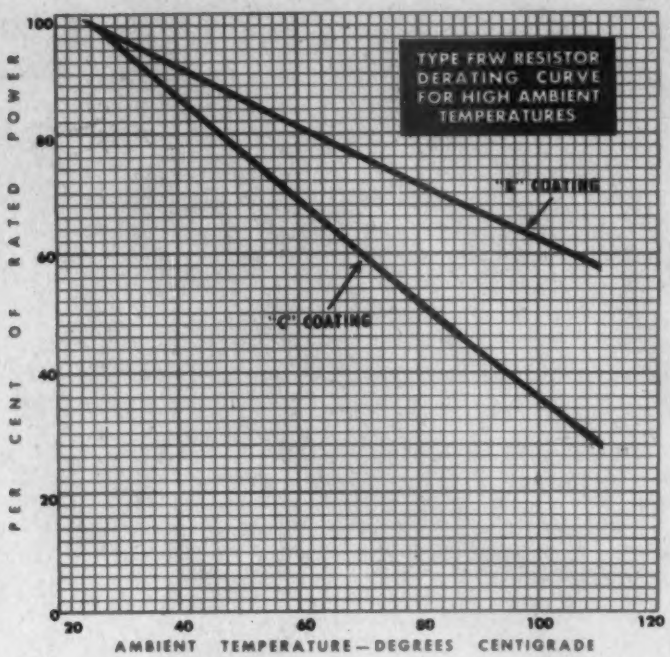
STANDARD IRC TYPE NUMBERS, DIMENSIONS and RESISTANCE RANGES

IRC Type	IRC Power Rating (See Note)		Corresponding JAN Type	Dimensions			Minimum Ohms Available	Max. Ohms Available Wound With 0.0025" diam. wire	Max. Ohms Available Wound With 0.001" diam. wire
	"B" Coat	"C" Coat		A Mounting Centers	B Ceramic Length	C Overall Length			
FRW-20	20 w.	8 w.	RW-20	2"	1¼"	2½"	0.5	2,000	9,500
FRW-21	30 w.	12 w.	RW-21	2⅝"	2"	3¼"	0.5	5,000	23,000
FRW-22	50 w.	20 w.	RW-22	4¼"	3½"	4¾"	0.75	11,000	50,000
FRW-23	65 w.	26 w.	RW-23	5½"	4¾"	6"	1.0	15,000	80,000
FRW-24	75 w.	30 w.	RW-24	6¾"	6"	7¼"	1.5	21,000	100,000

NOTE: IRC RATINGS are based upon temperature rise of 250° C. for "B" Coat and 130° C. temperature rise for "C" Coat, for single resistors, mounted on a steel plate 12" x 12" x 1/16", in free air. For resistors mounted on a non-metallic surface, it is recommended that the standard power rating be reduced by 15%.

IRC POWER WIRE WOUND CHARACTERISTICS


TEMPERATURE RISE CURVES OF IRC POWER RESISTORS MOUNTED ON 12"x12"x1/16" STEEL PLATE IN FREE AIR
"B" COATING
"C" COATING
TEMPERATURE RISE IN DEGREES CENTIGRADE
POWER IN PER CENT OF RATED WATTS LOAD


TYPE FRW RESISTOR DERATING CURVE FOR HIGH AMBIENT TEMPERATURES
"B" COATING
"C" COATING
PER CENT OF RATED POWER
AMBIENT TEMPERATURE—DEGREES CENTIGRADE

DERATING. If necessary to operate Type FRW Resistors in an ambient higher than 25° C., it is recommended that they be derated according to the Derating Curve for High Ambient Temperatures. For example, if the resistor is normally a 50-watt type and is to operate at 60° C. ambient, it should not be loaded to more than 82% of 50 watts, or 41 watts.

COATINGS. Coatings "B" and "C" are especially developed cement coats, having as common characteristics neutral chemical reaction, processing temperatures not over 200° C. and extreme denseness. Through the use of low temperatures in processing the ceramic, wire and terminals maintain maximum life and strength, thus insuring long life at normal loads.

TYPE "B" COATING. Type "B" Coating is designed for high-temperature requirements where wire size is large enough to insure dependability. In Table A, the power ratings for Type "B" coat are based on a temperature rise of 250° C., from a 25° C. ambient. This coating is well suited to the requirements for normal humidity conditions.

TYPE "C" COATING. Type "C" Coating is a specially developed organic cement coat, designed to withstand the most extreme conditions . . . such as on shipboard, in tropical countries, and extremely humid climates. Power ratings shown in Table A for this Coat are based on a temperature rise of 130° C. above an ambient of 25° C. in free air. At no time should the total temperature (ambient plus rise) exceed 160° C.

TOLERANCE. On single and multi-section resistors, ±10% is standard tolerance. On single section resistors only, ±5% is available for resistance values above 50 ohms.

MULTI-SECTION RESISTORS. Tapped Resistors may be supplied, within the limitations of the resistor size used as listed below. The use of taps results in a reduction in total resistance available, due to loss of winding space. When specifying Tapped Resistors, provide wattage per section.

FRW-20	Single section only.
FRW-21	Two sections maximum.
FRW-22	Three sections maximum.
FRW-23	Four sections maximum.
FRW-24	Five sections maximum.

TERMINALS. Securely clamped around the ceramic winding form by spot welding; heavily hot-tin dipped for easy soldering.

BRACKETS. Non-magnetic metal brackets, so designed that resistors are readily mounted by rivets or screws. Bracket holes will clear #10 Machine screw.

MARKINGS. Permanently marked with type number and resistance.

WINDING FORMS. Highest grade, non-hygroscopic ceramic winding form, chosen for mechanical strength, resistance to thermal shock and freedom from moisture absorption.

WIRE. Copper-nickel and nickel-chrome alloys, largest sizes compatible with adequate spacing, wound with uniform spacing and tension.

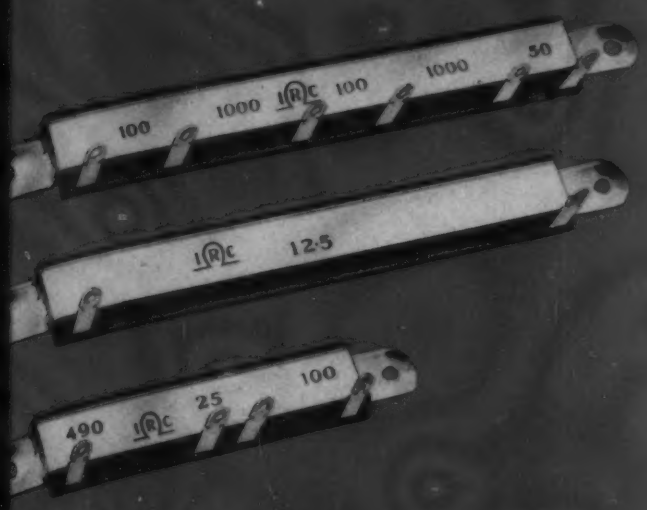
INSULATION. 3000 volts A. C., R. M. S., between terminals and bracket.

MECHANICAL STRENGTH. Will withstand a transverse load in excess of 25 pounds without mechanical or electrical damage.

CATALOG DATA BULLETIN

Important information for Engineering and Purchasing Depts. Please file with your IRC Catalog.
INTERNATIONAL RESISTANCE CO., 401 N. Broad St., Philadelphia 8, Pa., U. S. A.
In Canada: International Resistance Co., Ltd., Toronto, Licensee

TYPE MW



WIRE WOUND RESISTORS

Because of its radical departure from conventional design, the type MW Insulated Wire Wound Resistor is unsurpassed for adaptability to an extremely wide variety of design requirements. Completely insulated and protected, these flat type resistors are encased in durable molded phenolic compound and mounted with a metal bracket of unique design. The mounting bracket actually transfers heat from inside the chassis to the outside, thus providing unusually rapid heat dissipation.

The type MW is virtually impervious to the elements, including moisture and salt spray—the common causes of trouble in ordinary wire wounds.

Many excellent opportunities for cost reduction are offered by use of the MW with its low initial cost, lower mounting cost, flexibility in providing taps at low cost, and saving in space.

Equally important, is the common-sense wattage rating established for the MW, in that it is rated at 100°C. to conform with modern engineering practice. Unlike most wire wounds, the MW may be operated at its full "on plate" rating, whether enclosed or not, without exceeding its rated temperature rise of 100°C. This permits, for example, the use of an MW 5 at 20 watts where a 60 watt tubular resistor would normally be required.

CONSTRUCTION

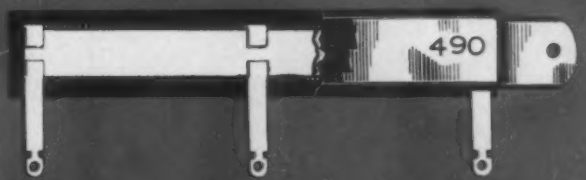
The Type MW is a flat wire wound resistor strip, permanently enclosed by high pressure molding in a special asbestos-filled phenolic compound. A permanently attached metal bracket with mounting feet permits mounting of the resistor on any flat metal surface, thus allowing rapid dissipation of heat.

TERMINALS. Standard Terminals are of rolled edge. heavily tinned strip punched with hole to take No. 14 B & S gauge wire and side notches for wrapping connections. Contact to the resistance element is made by clamping the specially formed terminal under high pressure.

Design of the terminal is such that no sheared edge can ever come in contact with the resistance wire, thus precluding the possibility of nicked wires.

MOUNTING BRACKETS. Standard mounting brackets of tinned steel (brass provided on special request). Designed with mounting feet to be bolted or riveted to any flat surface. By extending mounting feet of brackets, almost any requirement for distance between mounting centers can be met. "D" dimension plus 2" is maximum.

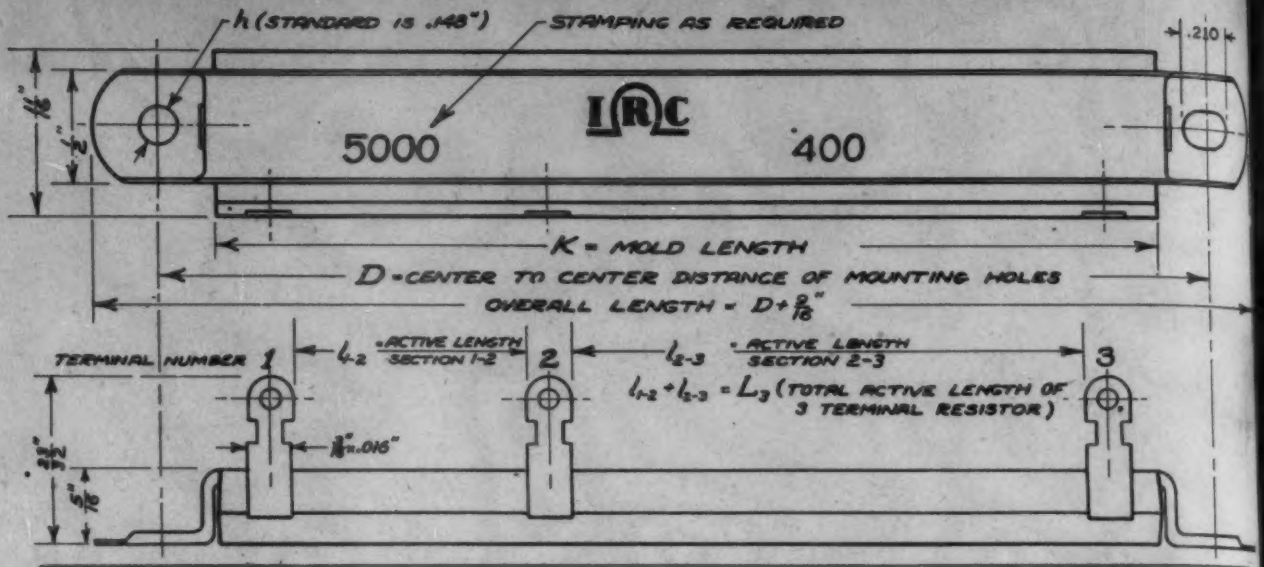
INSULATION. All resistors are rated and tested at 1000 volts R.M.S. 60 cycle (1400 Volt Peak) applied along entire length between element and metal plate between all terminals and ground.



CROSS SECTIONAL VIEW

SPECIFICATIONS

TYPE MW INSULATED WIRE WOUNDS



Unit Type IRC Designation	K = Mold Length	Dmin. = Minimum Mounting Center Distance (=IRC Std.)	Two Terminal Resistor Only*				Minimum length per section 1/3" between terminals Minimum value—3 ohms per inch of winding length Maximum value—7400 ohms per inch of winding length Minimum ohms given are based on No. 90 alloy wire						
			Rated Watts 100° C. Rise		Range in Resistance Value		Active winding length for Multi-Section Units						
			Free Air	On Plate	Min. Ohms	Max. Ohms	1 Sec.	2 Sec.	3 Sec.	4 Sec.	5 Sec.	6 Sec.	7 Sec.
MW-2	2"	2 1/2"	3.9	7.4	4.13	10,000	1.375	1.187	1.000	—	—	—	—
MW-3	3"	3 1/2"	5.8	10.9	7.13	17,500	2.375	2.187	2.000	1.812	1.625	—	—
MW-4	4"	4 1/2"	7.6	14.4	10.1	25,000	3.375	3.187	3.000	2.812	2.625	2.437	—
MW-5	5"	5 1/2"	9.5	17.9	13.1	32,500	4.375	4.187	4.000	3.812	3.625	3.437	3.250

NOTE—Specify resistance value and actual wattage load per section when ordering.

MARKING

Any required marking can be printed on the top of the mounting bracket.

OVERLOAD

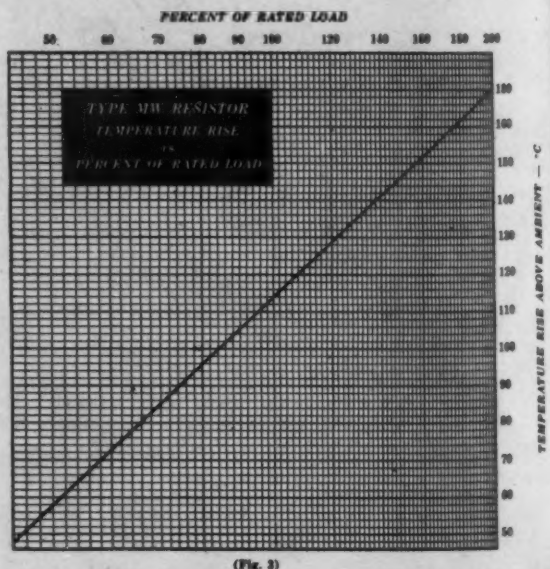
Conservative ratings and high heat dissipating efficiency allow overloads of 150% indefinitely with negligible adverse effects.

HUMIDITY

Continuous operation at 40° C. in an atmosphere of 90% relative humidity at any load—either AC or DC produces no effect on the resistor element—operation in a saturated salt spray bath for 1000 hours at 30° C. has no effect other than terminal corrosion. The resistor is virtually impervious to atmospheric conditions of any type.

TOLERANCE

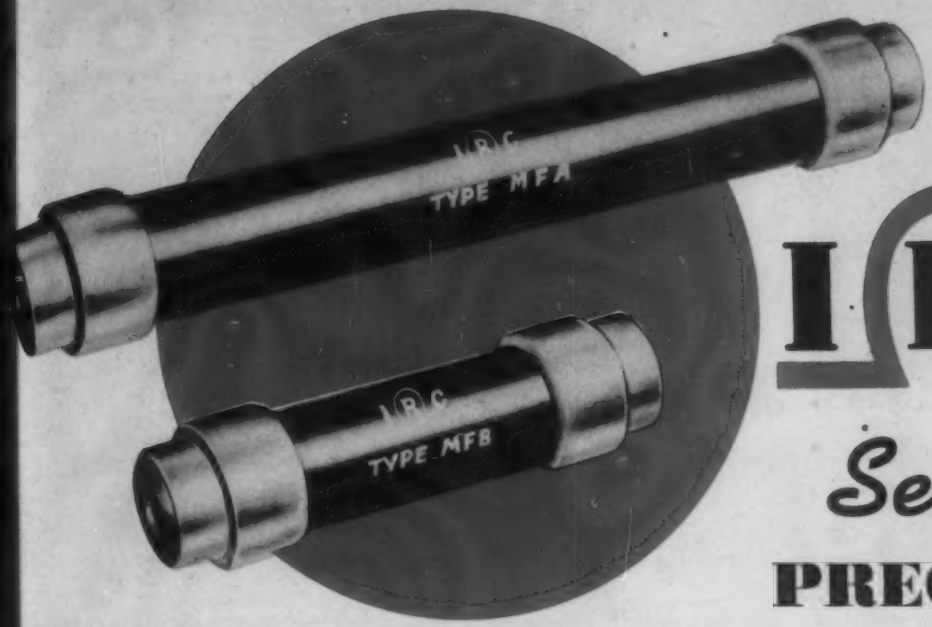
Standard Tolerance 10%—Closer tolerance available at extra cost.


PERCENT OF RATED LOAD
50 60 70 80 90 100 120 140 160 180 200
TYPE MW RESISTOR TEMPERATURE RISE vs PERCENT OF RATED LOAD
TEMPERATURE RISE ABOVE AMBIENT — °C
50 60 70 80 90 100 110 120 130 140 150 160

(Fig. 3)

CATALOG DATA BULLETIN

Important information for Engineering and Purchasing Depts. Please file with your IRC Catalog.
INTERNATIONAL RESISTANCE CO., 401 N. Broad St., Philadelphia 8, Pa., U. S. A.
In Canada: International Resistance Co., Ltd., Toronto, Licensee



IRC Sealed PRECISION VOLTMETER MULTIPLIERS

JOINT ARMY-NAVY SPECIFICATION — JAN R-29

...es MFA, MFB and MFC Resistors offer a proven solu... to the problem of finding suitable and dependable ...ipliers for use under the most severe humidity condi..., such as are encountered in marine service. They may ...used with the commonly available one milliampere DC instruments, as well as with other instruments. Sensitivities of 1000 ohms per volt or more may thus be obtained, which results in very little drain on the power supply. They are compact, rugged, stable, fully moisture-proof and easy to install.

...RATING

(a) *Current rating:* 1.0 milliamperes maximum.

(b) *Voltage rating:* The voltage rating in kilovolts is numerically equal to the resistance expressed in megohms, e.g., a 3 megohm resistor would be rated at 3 kilovolts.

TEMPERATURE COEFFICIENT

Not greater than 0.02% per degree centigrade over temperature range—40° to 100° C.

SURFACE TEMPERATURE RISE

Not over 25° C. at standard voltage rating.

INTERNAL TEMPERATURE RISE

Not over 55° C. at standard voltage rating.

FREQUENCY CHARACTERISTICS

Resistance non-inductively wound. Resistance varies less than ±1% at any frequency up to and including 1,000 c.p.s.

DIELECTRIC STRENGTH

Multiplier will withstand a voltage of more than 20,000 volts peak between center band around resistor and shorted terminals.

WIRE

Nichrome and advance enameled. .0015" diameter minimum.

TERMINALS

Monel metal ferrules suitable for mounting in 60 ampere form #1 fuse clips.

INSULATION RESISTANCE

Greater than 10,000 megohms.

FERRULE SECURING

Ferrules will resist a torque greater than 5 inch pounds without shifting or loosening.

TRANSVERSE LOADING

Resistor will withstand transverse load of more than 25 lbs.

RESISTANCE TO HUMIDITY

The resistor will withstand more than 9 cycles of the following test without changing more than 1%:

(a) Keep resistor at temperature of 80° C. for 5½ hours and then measure resistance.

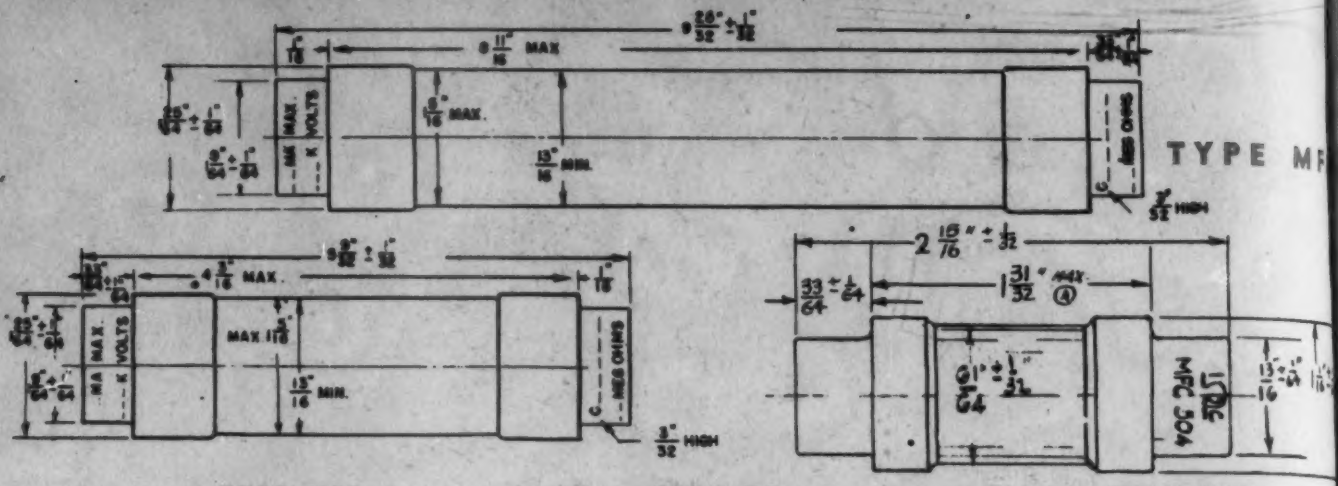
(b) Immerse resistor in 65° C. saturated salt solution for 2 hours.

(c) Transfer to bath of 0° C. saturated salt solution for 2 hours. Wash in clear water.

(d) Maintain resistor at 80° C. for ½ hour.

(e) Apply rated voltage for 1½ hours.

VOLTMETER MULTIPLIERS



Type	Resistance Megohms	K. Volts	Navy Type No.
MFB 105	1.0	1.0	63754
MFB 155	1.5	1.5	63755
MFB 205	2.0	2.0	63747
MFB 255	2.5	2.5	63774
MFB 305	3.0	3.0	63825
MFB 355	3.5	3.5	—

Type	Resistance Megohms	K. Volts	Navy Type No.
MFA 355	3.5	3.5	63775
MFA 405	4.0	4.0	63815
MFA	4.5	4.5	—
MFA 505	5.0	5.0	—
MFA 605	6.0	6.0	—

Type	Resistance Megohms	Maximum Current M.A.	K. Volts
MFC 504	0.5	1.0	0.5
MFC 804	0.8	1.0	0.8
MFC 105	1.0	1.0	1.0

IRC PRECISION WIRE WOUND RESISTOR SPECIFICATIONS

WW-1
WW-2

WW-3

Type	Wattage	Length	Diameter	RANGE Minimum	RANGE Maximum	Terminal	Winding
WW-1	Below .36 meg. 1 watt—above 600 volts max.	2 1/8"	9/16"	.1 ohm	600,000 ohms	Binding Post and nut	Non-inductive
WW-2	Below 1 meg. 1 watt—above 1,000 volts max.	2 15/16"	7/8"	.5 meg.	2.5 meg.	Binding Post and nut	Non-inductive
WW-3	Below 40M ohms 1 watt—above 200 volts max.	9/16"	9/16"	1.0 ohm	150,000 ohms	lugs leads	Non-inductive
WW-4	Below .16 meg. 1 watt—above 400 volts max.	1"	9/16"	.1 ohm	600,000 ohms	lugs leads	Non-inductive
WW-5	Below .2 meg. 1 watt—above 400 volts max.	1 1/4"	3/4"	.25 ohm	1.0 meg.	lugs leads	Non-inductive

WW-4

WW-5

CONSTRUCTION

CERAMIC — The winding form of these units is made of a non-hygroscopic ceramic having high insulation qualities, high mechanical strength and low coefficient of expansion.

WIRE — Only ample size, special alloy wire, specially enamelled to meet a rigid insulation test, is used in making these units. Not less than .0014" in diameter.

IMPREGNATION – The winding is impregnated with a special varnish, which improves the insulation and eliminates breakdowns and shorted turns. The characteristics of this impregnating compound are such that it hardens with high temperatures instead of softening as is the case with the wax impregnation found in the average wire wound resistor. Almost complete protection from the effects of high humidity results from this impregnation.

TECHNIQUE — Special attention has been paid to insure transfer of special enamelled wire to winding form without strain or break in insulation. Special tests such as voltage flash, etc., are utilized to indicate possible shorted turns thus insuring finest quality.

TERMINALS — To insure positive connection at the terminals the exclusive IRC molded contact is employed on these units. This eliminates the weakness encountered in a mechanically clamped, soldered or welded contact and forestalls contact resistance, loose connections and noise.

TOLERANCE — Standard 1.0% tolerance. ½, ¼ and 1/10% are available. ¼ and 1/10% tolerance are measured with a temperature correction to 68°F.

TEMPERATURE COEFFICIENT — Up to approximately 25% of maximum value shown—.002%/°C. Beyond 25%—.017%/°C.

INTERNATIONAL RESISTANCE COMPANY
401 N. BROAD ST., PHILA., PA. • IN CANADA International Resistance Co., Ltd., Toronto, Licensee

PERMANENT MAGNETS MAY DO IT BETTER

We are your Assistants . . . NOT your Competitors . . .

We make no end products. We have no allied branches. These two facts are important to our customers. They can discuss their problems and product designs freely with us, knowing that their confidence will be respected. Thus your problem becomes our problem, and our advantage of 37 years of permanent magnet designing becomes your advantage.

This is only one of the many reasons why The Indiana Steel Products Company is headquarters for Permanent Magnet research, why more than 25,000 individual applications have been developed by our engineers, why we are the world's largest producer of permanent magnets which utilize every conceivable permanent magnet material.

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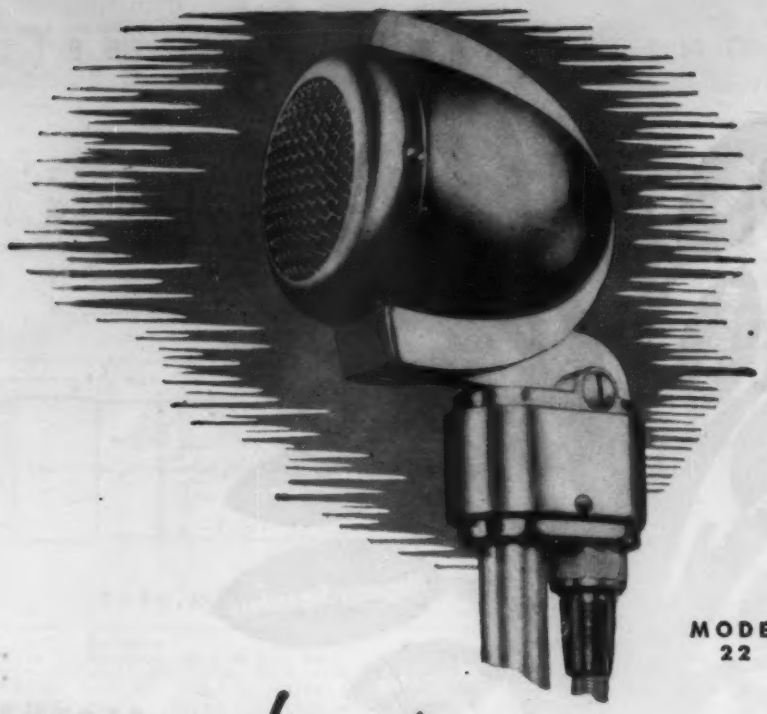

MODEL 22

Microphones of **DISTINCTION**

● When you select a TURNER Microphone for better performance you automatically choose the leader in style and dependability. The accurate pickup, smooth response, and enduring reliability of TURNER design and construction is recognized the world over. Where performance counts most you'll Turn to TURNER.

THE MODEL 22—This handsome streamlined unit gives "smooth-as-silk" performance. Adds distinction to any installation. Ideal for both voice and music pickups. Widely used for all-around recording, public address, call system, and communications work. 90° tilting head permits semi- or non-directional operation. Available in a choice of high quality crystal or dynamic circuits. Complete with 7 ft. removable cable set. Ask your dealer.

WRITE FOR COMPLETE MICROPHONE CATALOG

Microphones by **TURNER**

THE TURNER COMPANY

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MICROPHONES LICENSED UNDER U.S. PATENTS OF THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY, AND WESTERN ELECTRIC COMPANY, INCORPORATED. CRYSTALS LICENSED UNDER PATENTS OF THE BRUSH DEVELOPMENT CO.

that the oscillator output is held quite constant regardless of tube, line-voltage or other variations.

The output circuit for the secondary probe coil consists of a diode peak rectifier and a d-c voltmeter. Cancellation of initial coupling is accomplished by adjusting the zero set control which inserts a bucking voltage in series with the rectified probe input.

Any pentode or beam power tube is suitable as an oscillator. A 25L6 using a 115-volt plate supply is adequate for driving one micrometer at 50-volt-amperes. A single 807 is capable of supplying 1,000 volt-amperes, more than enough for four micrometers.

Micrometer Performance

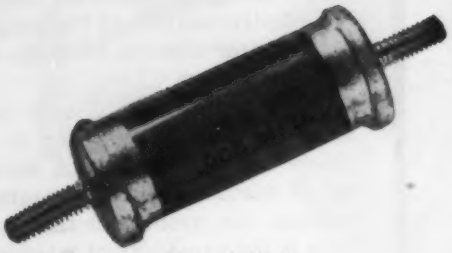
The metal used as a reference surface has some influence upon the performance of the micrometer. While there is still a significant change in mutual inductance when magnetic materials are used, a relatively large initial coupling and a loss in scale factor are manifested. Ferromagnetic materials have appreciable permeability effects at radio frequencies so that there is an opposing effect added to the reduction in coupling caused by eddy currents. As the frequency is increased, the performance with ferromagnetic materials tends to improve, but nonmagnetic metals are still preferable.

Very little difference in performance can be observed between surfaces of various nonmagnetic conducting materials. Brass works equally well as silver, for example. At a frequency of 3 mc, it has been found that the metal need be only about 0.0001 inch thick; what lies beneath this layer does not matter. Thus, a convenient way to make measurements with magnetic materials is to plate them with a layer of copper or silver, for instance, to a thickness of 0.001 inch.

If the diameter of the metal plate is greater than 1½ times that of the larger probe coil, there appears to be little further effect due to the size of the plate. For most applications, it is suggested that the plate be no smaller than the coil. A hole in the center of the plate is not particularly detrimental to performance in those cases where lightness

Now Available---

A Line of PLASTICON* GLASSMIKE RF Transmitting Capacitors



(actual size)

Superior to mica capacitors because:

- **Greater safety factor (3500 VDC Operating; 7500 VDC Test)**
- **Lower RF losses (See current rating below)**
- **More conveniently mounted**
- **Less chassis space**
- **Smaller overall volume**
- **Impervious to moisture (The GLASSMIKE construction is 100% sealed)**
- **Silicone-fluid filled**

The above advantages are possible by the use of the Type L film dielectric which has lower losses than mica.

● ● ●

TYPE LSG — PLASTICON* GLASSMIKES

3500 VDC Operating — 7500 VDC Test

Cat No.	Cap. Mfd.	Dimensions OD Length	Current Rating in RF Amperes 100 Kc	300 Kc	1 Mc	3 Mc	List Price
LSG500	.00005	19/32"x1-3/16"	.02	.05	.16	.47	$1.50
LSG101	.0001	19/32"x1-3/16"	.03	.09	.31	.94	1.50
LSG251	.00025	19/32"x1-3/16"	.05	.25	.5	2.2	1.50
LSG501	.0005	19/32"x1-3/16"	.15	.5	1.6	3.0	1.50
LSG102	.001	19/32"x1-9/16"	.31	.94	2.5	4.5	1.70
LSG202	.002	3/4" x1-9/16"	.62	1.9	4.5	7.0	2.45
LSG502	.005	3/4" x1-3/4"	1.6	3.1	6.0	7.0	3.50
LSG602	.006	29/32"x1-9/16"	1.9	3.5	6.2	7.0	3.75
LSG103	.01	29/32"x1-3/4"	3.1	5.0	7.0	7.0	4.25

*PLASTICONS—Plastic Film Dielectric Capacitors

Condenser Products Company

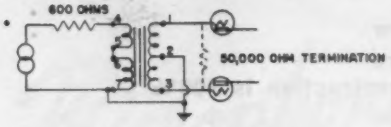
1375 NORTH BRANCH STREET • CHICAGO 22, ILLINOIS

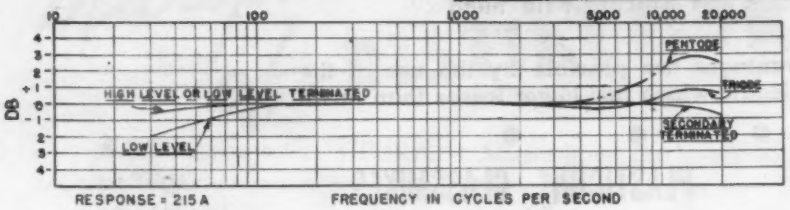
Compare PERFORMANCE of this ADC 2nd LINE TRANSFORMER

Typical of **ADC** design is this (type 215A) input transformer taken at random from stock and submitted to the tests shown below. The circuit diagram is included to allow you to run your own comparative performance tests.

215A Input Transformer
- Response ± 1½ db 50 to 10,000 cps.
- Ratio 600 to 50,000 ohms.
- Maximum operating level + 26 vu.
- Case, 14A (2"x2⅜"x3" high).

FREQUENCY RESPONSE





RESPONSE - 215A — FREQUENCY IN CYCLES PER SECOND

Low frequency response—(referred to 1000 cps) (High level + 26 vu, Low level −15 vu.):
Secondary unterminated, 30 cps, − 2.0 db at low levels.
Secondary terminated, 30 cps, − 0.7 db at low levels.
High frequency response—(referred to 1,000 cps):
Operating into triodes—unterminated, up to 15,000 cps, ± 1 db.
Operating into pentodes—unterminated, up to 15,000 cps, ± 3 db.
Operating into triodes or pentodes—terminated, up to 20,000 cps, ± 0.5
All response characteristics are well within catalog claims except the one high frequency condition. Since some difference in response will result in pentode on triode grids (due to reflected capacitance) it was thought most desirable in designing this transformer, to flatten the triode response, permitting the pentode response to rise. This rise is often desirable to correct for other elements, but if not desired, is readily removed by simple termination, providing versatile usage.

Under an ideal condition, response flat within ½db from 30 to 20,000 cps is obtainable, but since this is not typical of all applications a rating on this basis would be misleading.

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AUDIO DEVELOPMENT

Audio Development Co.
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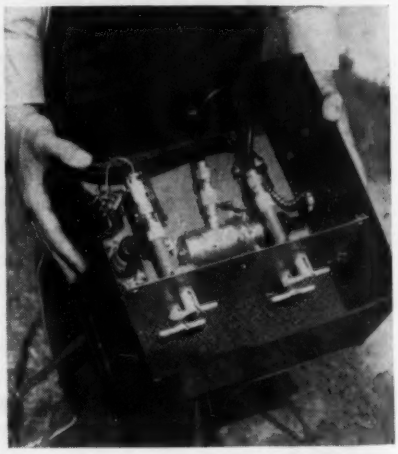
of the metal plate or vane is important.

If the surface of the metal is curved, the indicated reading is relative to some average displacement. The initial mutual inductance is larger, so that more buckout voltage is required, but incremental readings are very nearly the same as for a flat plate. There is no necessity to shape the end of the probe form to match the surface, as would be the case with capacitive micrometers. The useful linear range is reduced, however, because the effective surface of the metal is at a greater distance from the end of the coil form.

Some measurements have been made with the micrometer to examine the effect of placing materials of various dielectric constants between the probe and the metal. This is the usual way of measuring insulation thickness. It was found that any error resulting from the dielectric constant is so small as to be within the accuracy of the instrument.

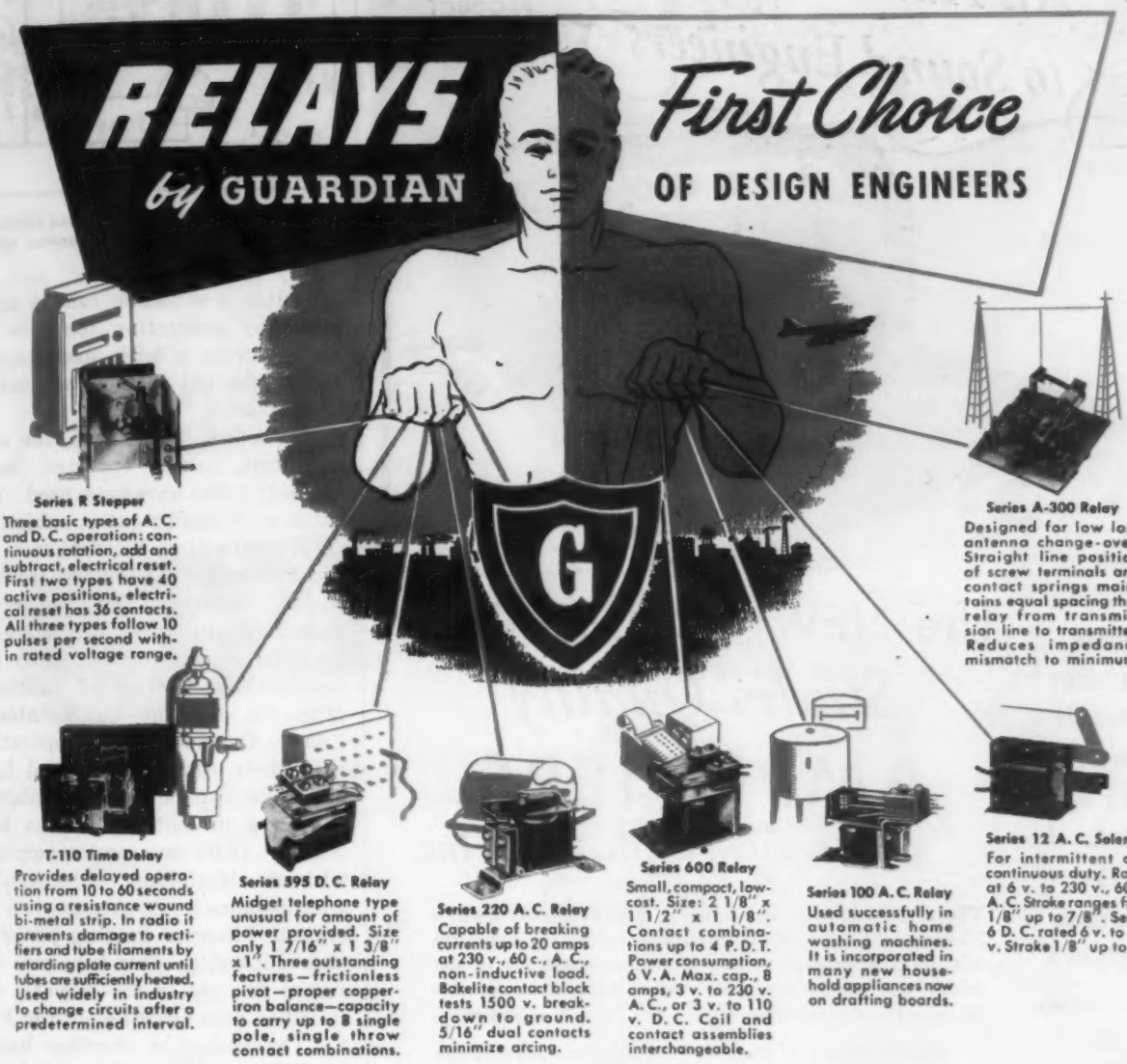
The electronic micrometer was developed in connection with projects for the Navy Department, Bureau of Ships, by M. L. Greenough and W. E. Williams of the Electronic Instrumentation Laboratory of the Bureau of Standards. A patent application has been taken out in the name of the United States Government and will be made available to industry without charge.

SPEED COP AGAIN



Close-up view of the electronic portion of the speed cop for clocking motorists (ELECTRONICS, July 1947, p. 148). The transmitter is at right with its antenna; the receiver is at left. An insulating panel protects the antennas from damage

THOUSANDS OF SUCCESSFUL *Control* APPLICATIONS PROVE



Series R Stepper
Three basic types of A. C. and D. C. operation: continuous rotation, add and subtract, electrical reset. First two types have 40 active positions, electrical reset has 36 contacts. All three types follow 10 pulses per second within rated voltage range.

T-110 Time Delay
Provides delayed operation from 10 to 60 seconds using a resistance wound bi-metal strip. In radio it prevents damage to rectifiers and tube filaments by retarding plate current until tubes are sufficiently heated. Used widely in industry to change circuits after a predetermined interval.

Series 595 D. C. Relay
Midget telephone type unusual for amount of power provided. Size only 1 7/16" x 1 3/8" x 1". Three outstanding features — frictionless pivot — proper copper-iron balance—capacity to carry up to 8 single pole, single throw contact combinations.

Series 220 A. C. Relay
Capable of breaking currents up to 20 amps at 230 v., 60 c., A. C., non-inductive load. Bakelite contact block tests 1500 v. breakdown to ground. 5/16" dual contacts minimize arcing.

Series 600 Relay
Small, compact, low-cost. Size: 2 1/8" x 1 1/2" x 1 1/8". Contact combinations up to 4 P. D. T. Power consumption, 6 V. A. Max. cap., 8 amps, 3 v. to 230 v. A. C., or 3 v. to 110 v. D. C. Coil and contact assemblies interchangeable.

Series 100 A. C. Relay
Used successfully in automatic home washing machines. It is incorporated in many new household appliances now on drafting boards.

Series A-300 Relay
Designed for low loss antenna change-over. Straight line position of screw terminals and contact springs maintains equal spacing thru relay from transmission line to transmitter. Reduces impedance mismatch to minimum.

Series 12 A. C. Solenoid
For intermittent and continuous duty. Rated at 6 v. to 230 v., 60 c., A. C. Stroke ranges from 1/8" up to 7/8". Series 6 D. C. rated 6 v. to 230 v. Stroke 1/8" up to 2".

Faced with responsibilities for the design and successful performance of their companies' products, American design engineers are eagerly turning to Guardian Electric *first* for relays and complete control assemblies. They find at Guardian a vast wealth of application and performance data, an expert engineering staff with more than a decade of specialized experience solving the most complex and widely diversified control problems. Such experience offers design engineers an *extra bonus value* thru practical suggestions and valuable specific recommendations given without cost or any obligation. Should your design call for a "special" control, Guardian has probably built the self-same principle you seek into one of its large line of *basic* type units. When such a *basic* type unit becomes the "special" you need thru slight variations, the savings in time and money are substantial, you circumvent die costs and beat delivery schedules in the bargain! Should special engineering be required, our staff is at your disposal. Write — call on Guardian for these excellent controls designed by Guardian engineers for engineers. Expert advice is yours for the asking to help you design better products thru improved techniques which are now so vital to meet competition.

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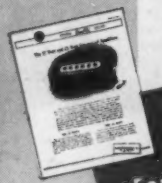
This new line of Commercial Amplifiers answers the great demand of Sound Engineers for commercial amplifiers embodying the proven principles of "custom-built" design so successful in Hollywood Studio Sound Equipment . . . The RESULT—high fidelity reproduction at any setting of volume controls up to full rated output; less than 4% distortion; versatility of application. These Amplifiers have an ease of operation and long life found only in Bardwell & McAlister Studio Quality Amplification Systems.



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ELECTRON ART
(continued from page 146)

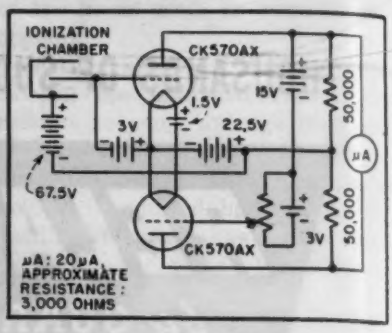

FIG. 4—Radioactivity meter uses nonmicrophonic subminiature electrometer tube

capacitance variation can be minimized by connecting the tube directly across a large fixed capacitance, if rapid changes are not to be measured.

In portable equipment, the subminiature, battery operated (hearing aid) tubes have been used. Because such equipment is subject to severe vibration, microphonics in these tubes are particularly troublesome. However the nonmicrophonic subminiature CK570AX electrometer triode (developed by the Special Tube Section of Raytheon Mfg. Co. for the U. S. Atomic Energy Commission in cooperation with their Argonne National Lab. and now commercially available) measures currents as low as 10^{-14} ampere (0.01 micromicroampere) without developing objectionable microphonics in its output when vibrated. Filament heating power is 12.5 milliwatts. This tube was designed for use in the recently declassified Zeus circuit shown in Fig. 4. The ionization chamber has a one-litre capacity, a 0.25 volt input across the grid resistor giving full meter deflection. The circuit constitutes a simple, portable, inexpensive meter for health surveys to protect personnel working with radioactive materials or x-rays.

Magnetron as D-C Amplifier

CONTROL of one current by another can be effected with a classical magnetron. (As originally used, "magnetron" meant a magnetically controlled diode, not an oscillator depending on the reaction of an alternating potential field on electrons moving in a static magnetic field. This abstract concerns the magneti-

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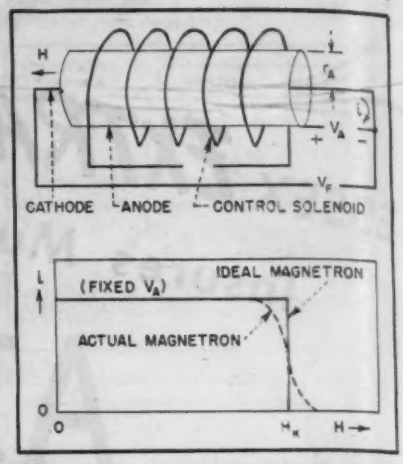

At the top is the basic magnetron connection: current in the solenoid produces a magnetic flux H. Below is the magnetron characteristic for a fixed anode-cathode potential, decreasing that potential moves the cutoff to the left, decreasing the heater current lowers the saturation current available at low magnetic flux

cally controlled diode.) The advantage of the magnetron over a grid controlled tube is that the controlling circuit can be at a radically different potential with respect to ground than the controlled circuit. Thus, in a particular x-ray application, the solenoid that was wound about the diode for control was at ground potential while the anode-cathode circuit of the diode was about 100 kv above ground in the target circuit of the x-ray tube. Furthermore, variations in solenoid-ground potential, except as they might affect the solenoid current, do not affect the output circuit, thus the magnetron is ideally suited to direct-current amplification.

Magnetic Sensitivity

The analogous paramaters amplification factor and internal resistance of a triode are magnetic sensitivity $\mu_M = (\partial v_A/\partial H)_i$ and internal resistance $R_i = 1/(\partial i/\partial V_A)_H$. In an ideal magnetron, current flows for a fixed value of anode-cathode voltage V_A until a critical magnetic field H_x is reached at which point the current abruptly drops from its saturation value to zero. However, in an actual magnetron, because of asymmetry in its radial and axial geometry and other variations especially edge effects of the electrodes, the discontinuity of current is less abrupt, being as shown in the accompanying drawing. For not too small values of V_A and H_x the mag-

VARIAC* VOLTAGE CONTROLS

THE Type V-5 VARIAC is the most popular of a number of different models. For over- and under-voltage testing, compensation for varying line voltages, and general a-c power, heat, speed and light control, its rating of 862 volt-amperes seems to cover a majority of applications.

We have been concentrating our VARIAC production facilities on this model and are gradually getting out of the woods.

The Type V-5, like others in the new 'V' series, is a decided improvement over its predecessors. Lighter in weight by 25%, with new unit brush construction which cannot cause damage to the winding if the brush wears down, having a heavy-duty lines switch, equipped with a polarity indicator in the convenience 'load' outlet, provided with a new molded terminal plate for either screw or solder connections, and furnished with a newly designed knob and dial with big calibration figures for reading at a distance, these new VARIACS are more convenient to use . . . more efficient in operation . . . last longer.

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SPECIFICATIONS†	115 VOLT—TYPE V-5	230-VOLT—TYPE V-5H
LOAD RATING (KVA)	.862	.575
Input Voltage	115	230 or 115
Output Voltage, ZERO to	135 or 115	270 or 230
Rated Current (Amps.)	5	2 or 1
Max. Current (Amps.)	7.5	2.5
PRICE—Unmounted (1)	TYPE V-5 $18.50	TYPE V-5H $21.00
PRICE—Cased (2)	TYPE V-5M 20.50	TYPE V-5HM 23.00
PRICE—Mounted (3)	TYPE V-5MT 25.00	TYPE V-5HMT 27.50

(1) At left in illustration
(2) Center of illustration
(3) At right of illustration
† All data for 60-cycle operation

The 230-volt models (V-5H) are similar in external appearance and size to the corresponding 115-volt (V-5) units shown in the illustration

** Reg. U. S. Pat. Off. VARIACS are patented under U. S. Pat. No. 2,009,013 and British Pat. No. 439,567. The VARIAC—and original continuously-adjusted transformer—is manufactured and sold exclusively by General Radio Company or its authorized agents.*

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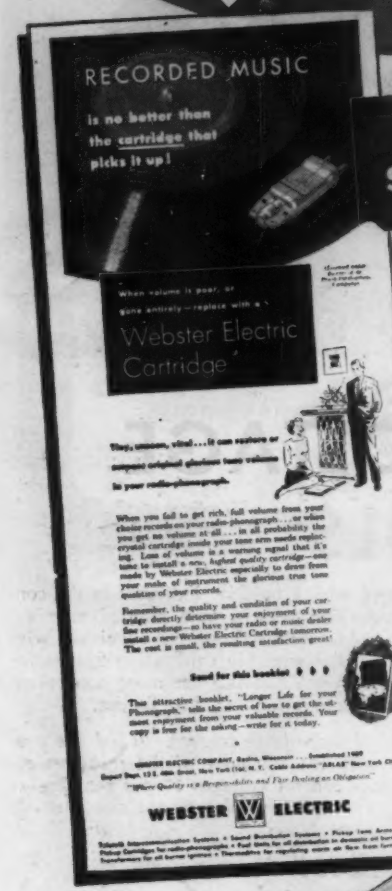
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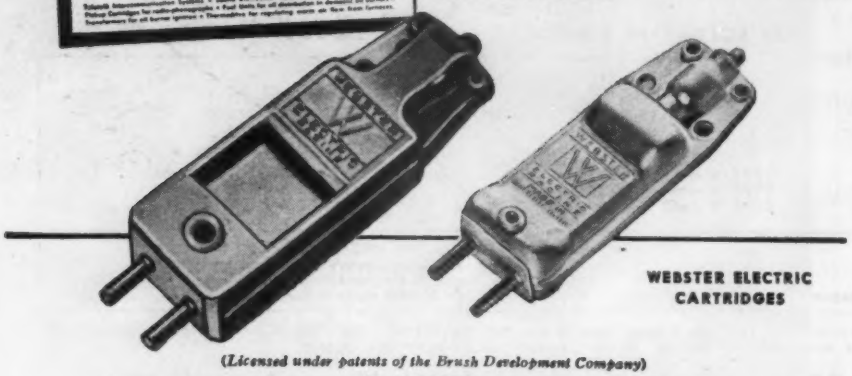
Webster Electric Cartridges are carefully designed and manufactured under highest quality standards. They have been on the market for years, and during this time have proved their value for long life and top performance.

In addition to cartridges, Webster Electric Company manufactures complete tone arm assemblies of improved design, in a wide selection of models.



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netic sensitivity can be taken as the slope of the magnetic characteristic curve, or as $\mu = 2(r_a/6.74)^2 H_z = (r_a/3.37)V_a^{1/2}$ in which r_a is the effective anode radius (its geometric radius if the cathode is of negligible radius and the tube is axially symmetrical).

If a grid is placed close to the anode and at cathode potential, the sensitivity of the magnetron will be increased because the magnetic field will then have an opportunity to deflect the electrons in a weak electric field over most of their path. If the amplification factor of the grid is G, the sensitivity of the grid magnetron is $\mu = 2G(r_a/6.74)^2 H$. The anode potential will have to be higher for the tube to conduct a reasonable current, but this is usually no drawback considering the enhanced sensitivity (A Magnetron for D. C. Voltage Amplification, H. B. G. Casimer, *Philips Technical Review*, p 361, Dec. 1946).

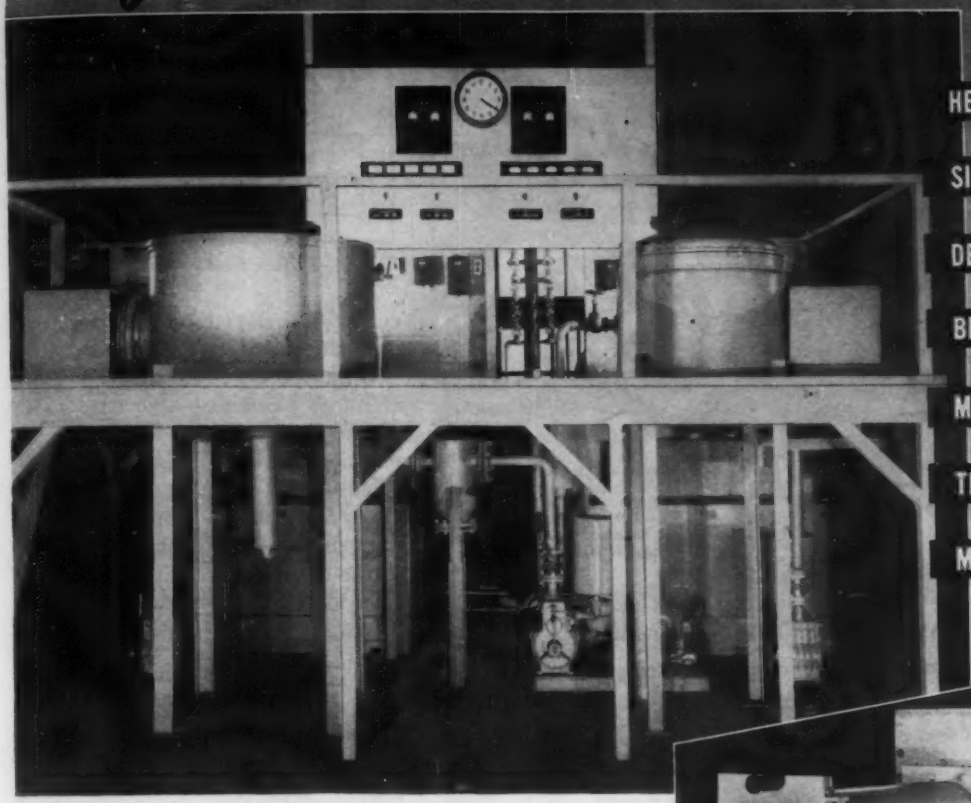
Measuring Distance Precisely

RELATIVE PHASE RELATIONSHIP between continuous-wave radio signals is used (as in an interferometer) to measure distance to accuracies within several inches per mile with the Raydist (radio distance) developed by Charles E. Hastings. Using a heterodyne system, circuit errors are canceled thus producing high precision. The equipment can be used in surveying, indicating positions of airplanes and their true ground speeds, plotting the trajectory of missiles, or maritime navigation. The equipment is light enough to be readily transportable.

Hyperbolic Coordinates

As used in most applications, the equipment is arranged as in Fig. 1. The mobile transmitter is carried by the vehicle whose position is to be measured. The system as shown provides one set of hyperbolic interference lines in space. Motion along the pattern is detected by the differences in phase at two a-m receivers. Operation is at 12,862.5 kc so that each half wavelength is 38.225 feet. The beat frequency developed at an a-m re-

High Vacuum FURNACES



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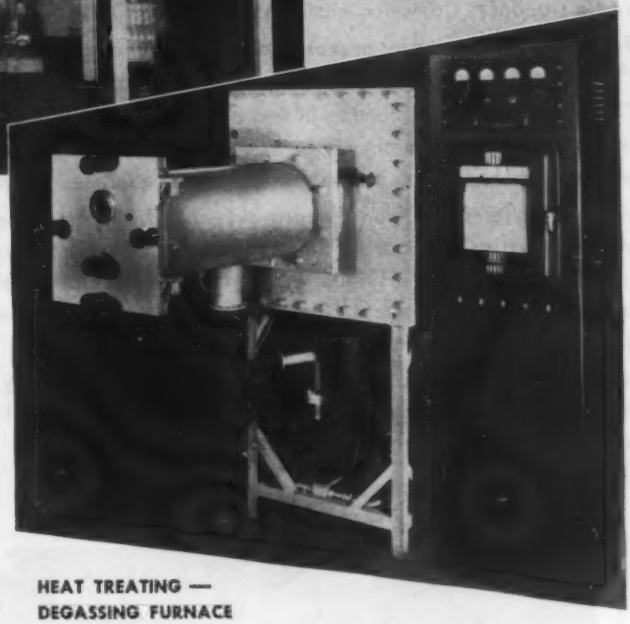

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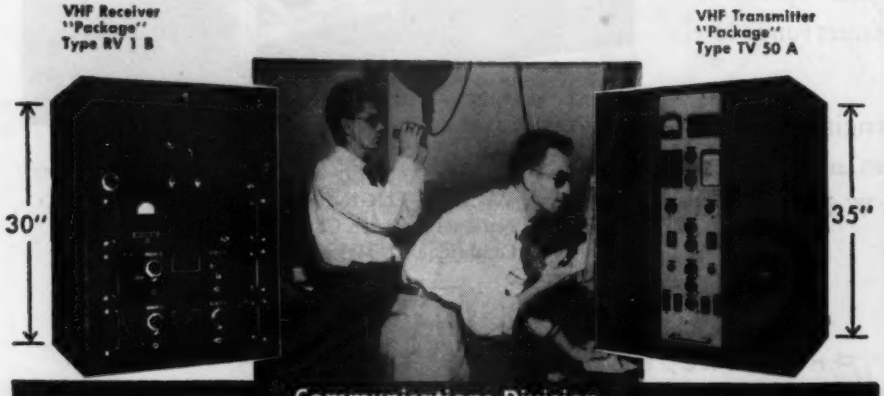

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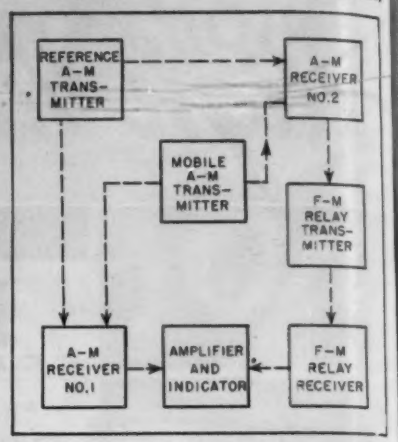


FIG. 1—Airline distance is measured with this setup

ceiver is relayed by f-m radio or land line to the amplifier-indicator.

Such an arrangement of equipment as described above indicates range from a reference point. If position is to be indicated, an additional a-m receiver is added and the beat frequency developed by it used with the beat frequency from either of the other two receivers to obtain an additional coordinate thus giving a fix.

Phase Integration

The beat frequency developed at each a-m receiver as a consequence of its receiving signals from two transmitters, the fixed reference one and the mobile one, is fed as a phase shift through the amplifier shown in Fig. 2 to a counting synchro. As the received phases change, the synchro rotor revolves driving the distance counter. Because the frequency of the beat is proportional to the speed of the mobile transmitter, true ground speed of an aircraft can be indicated by feeding the beat frequency to a direct-reading frequency meter calibrated in units of speed.

That only the frequency of the

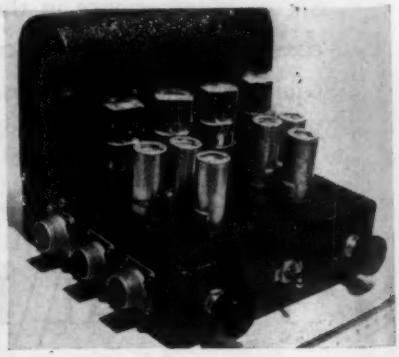
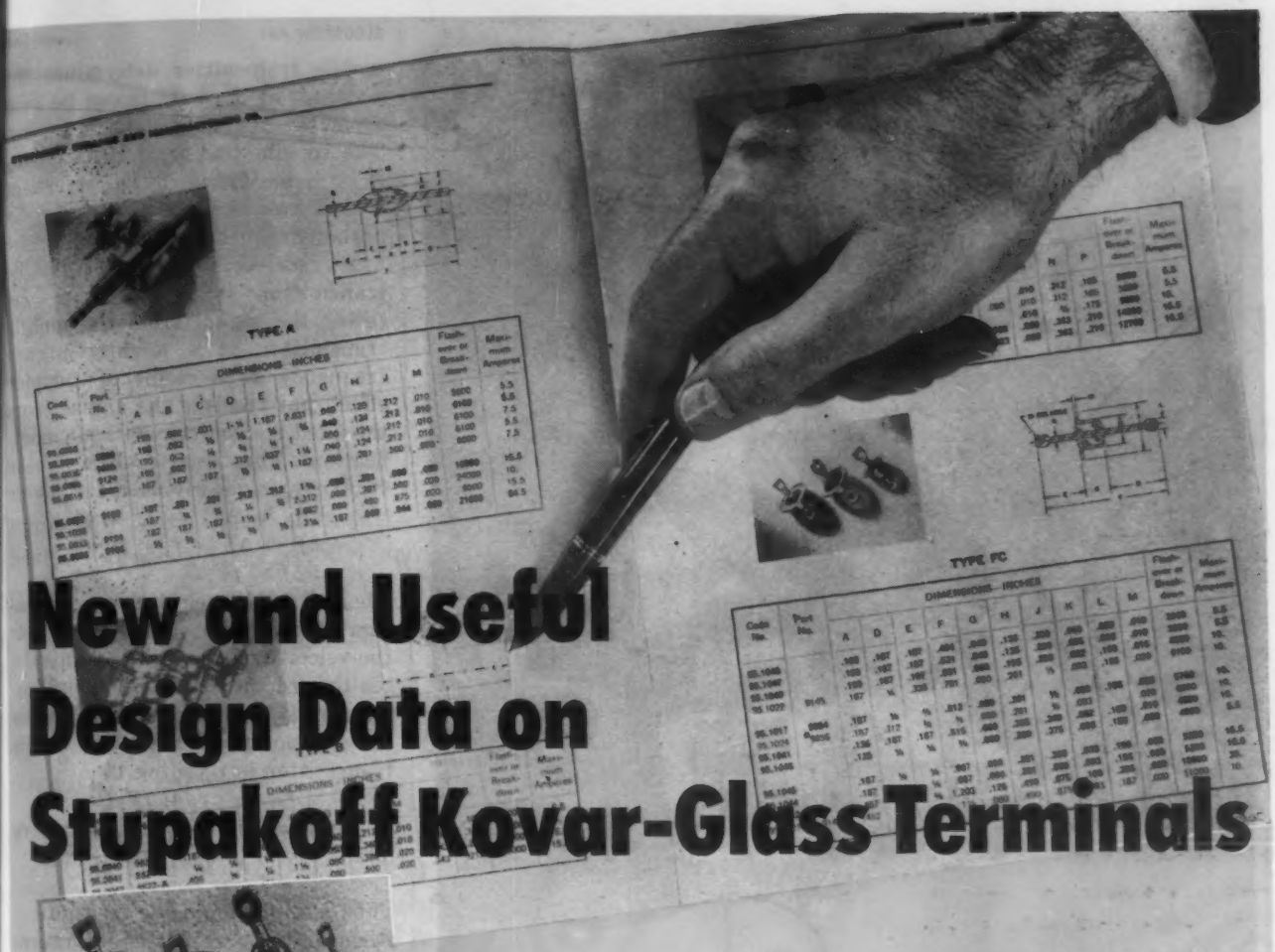
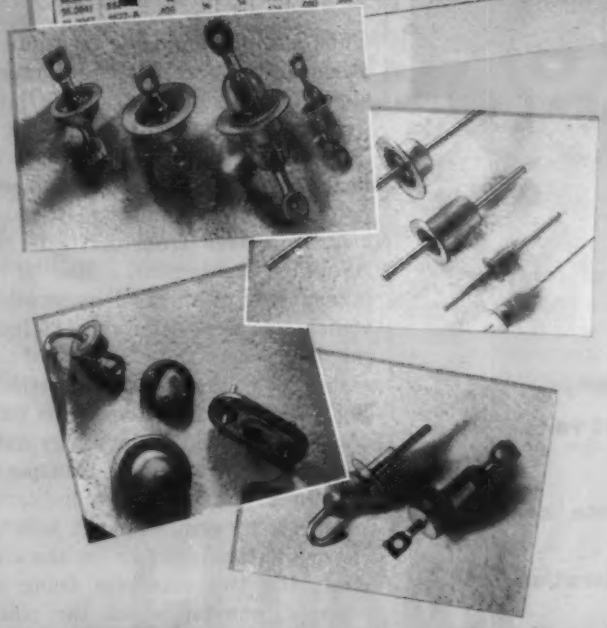


FIG. 2—Two-channel amplifier drives distance indicator



New and Useful Design Data on Stupakoff Kovar-Glass Terminals



Complete dimensions, capacities and ratings for more than one hundred and sixty different standard Stupakoff Kovar-Glass Terminals are included in Bulletin 447, pages of which are reproduced above. In addition to these, Stupakoff is prepared to make special designs when required. The illustrations at the left show a few of the varieties of terminals listed in this bulletin. If you use—or expect to use—metal-glass terminals, you should have a copy of this informative data book. Send today —it's free!

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They have a small negative temperature coefficient of resistance ranging from 0.08 per cent per degree C. for low resistance values up to 0.12 per cent per degree Centigrade, for resistance values up to 0.1 megohm.

Type "A" resistors in R.M.A. values are calibrated by the comparison method on the voltages specified in Joint Army and Navy specification JAN-R-11. Type "A" resistors can be manufactured in any size and resistance range listed in the accompanying tables. The Carborundum Company, Globar Division, Niagara Falls, N. Y.

TABLE I

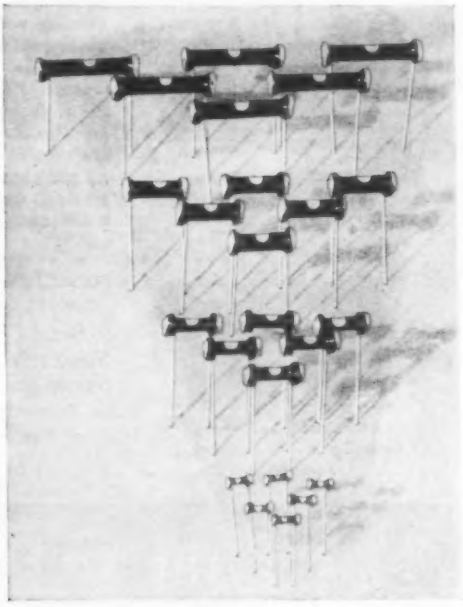
Part Number	Rating in Watts	Resistance Range*	Overall Length Inches	Overall Diameter Inches	Tinned Wire Length	Copper Leads Diameter
997-A	1/5	10 Ohms — 4.7 Megohms	21/64	7/64	1 1/8"	0.016"
763-A	1/4	10 Ohms — 15 Megohms	5/8	7/32	1 1/2"	0.032"
759-A	1/2	10 Ohms — 15 Megohms	3/4	1/4	1 1/2"	0.032"
766-A	1	10 Ohms — 15 Megohms	1 1/8	1/4	1 1/2"	0.032"
792-A	3	10 Ohms — 150000 Ohms	1 7/8	15/32	1 1/2"	0.040"
774-A	5	10 Ohms — 220000 Ohms	2 5/8	15/32	1 1/2"	0.040"

*R.M.A. Values ± 10% and ± 20% only.

TABLE II

Diameter in Inches	Resistance in Ohms Per Inch of Length		Length in Inches		RATING
	Minimum	Maximum	Minimum	Maximum	
1/2	10	250000	2	5	Continuous Duty Rating is based on one watt per sq. in. of external radiating surface.
5/8	7	250000	2	10	
3/4	3	100000	3	18	
1	2	50000	4	18	

Resistors listed in Table II can be supplied with metallized ends of brass, copper, nickel, tinned brass or tinned copper, also with tinned copper wire (No. 14 B.S.G.) leads approximately six inches long. Resistance tolerances on Type "A" Resistors limited to ± 10% and ± 20% only.



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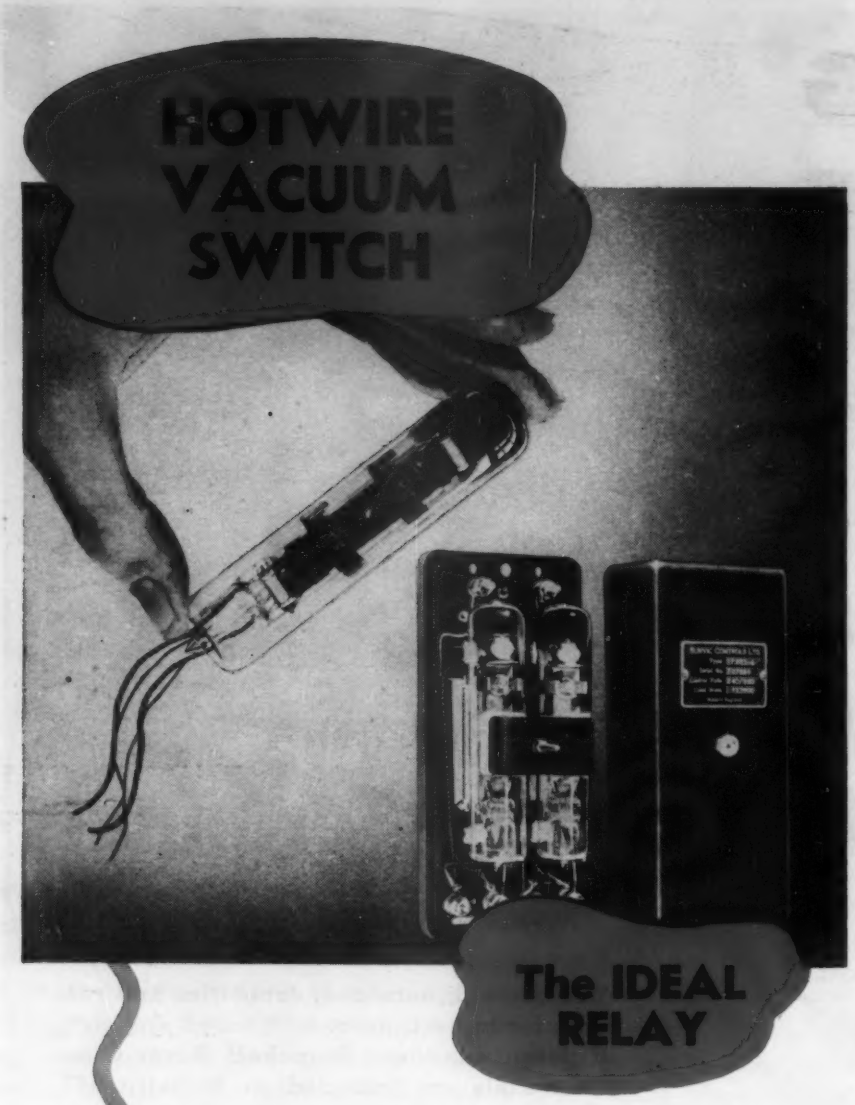

- Operates as voltage relay, current relay or time delay switch.
- Suitable for A.C. or D.C.
- Control circuit current 25-80 milliamps.
- Load current up to 30 amps at 440 volts.
- Silent.
- Non-inductive control circuit—hence control circuit contacts don't deteriorate.
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mobile transmitter determines the accuracy of the system can be seen from the following considerations. The mobile transmitter frequency f is heterodyned by a reference transmitter operating on a slightly higher frequency $(f + \Delta f)$. The first receiver, which the mobile transmitter is approaching, receives the signal from the mobile transmitter at a slightly higher frequency as a result of Doppler effect, but receives the signal from the fixed transmitter without modification. This receiver beats these two frequencies giving a frequency

$$f_{R1} = (f + \Delta f) - (f + fV/C)$$
$$= f + \Delta f - f - fV/C$$
$$= \Delta f - fV/C$$

where C is the velocity of propagation of the radio signals, and V is the velocity of the mobile transmitter toward the first receiver. Similarly, the frequency developed by the receiver from which the mobile transmitter is receding is

$$f_{R2} = \Delta f + fV/C$$

These two heterodyne signals are mixed giving a beat frequency

$$f_B = f_{R1} - f_{R2} = 2fV/C$$

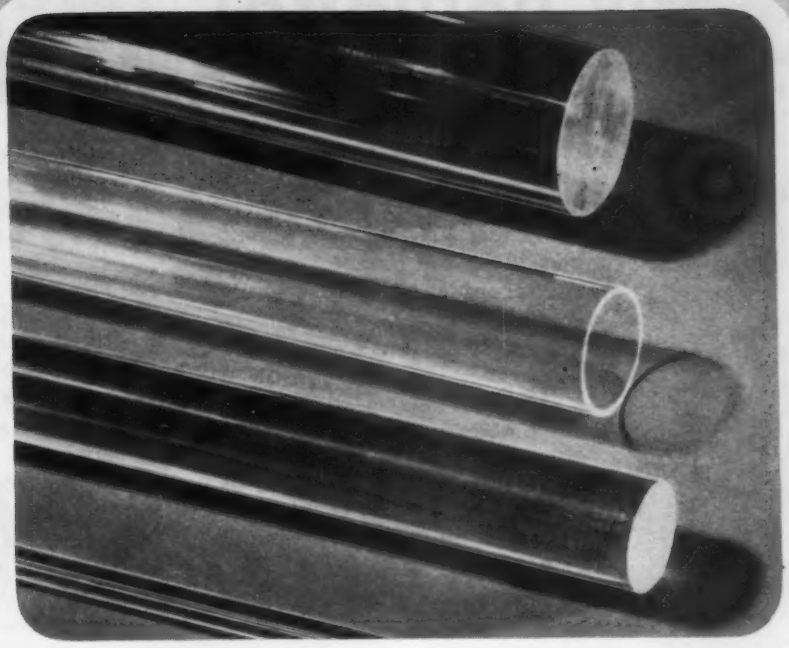
Thus all but the mobile transmitter frequency, the velocity of propagation, and the desired speed (integrated into distance) cancel out.

Because the system compares beats produced at two different points from the same two frequencies, it is free from drifts in the receiving equipment. Use of a transmitter in an airplane or other vehicle whose position is to be indicated increases the efficiency of the system over that of radar methods depending on reflections from passive targets, and is more accurate than methods relying on transponders. In applications, the indicator can be at any position, such as with the mobile transmitter on the airplane, the two receivers being at airports between which the plane flies and the reference transmitter between them. The system is especially useful in measuring velocity of propagation of radio waves.

Vertical Position Indicator

GAS-FILLED Y-type position convectron tube develops an unbalance voltage proportional to the sine of the angle of rotation from the vertical. Thus the tube is a useful

A "JEWEL" OF A PLASTIC



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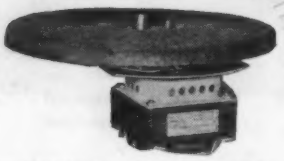
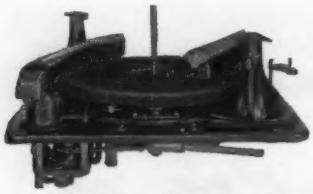


GI-RM4 Rim Drive, Heavy Duty Electric Recording Motor



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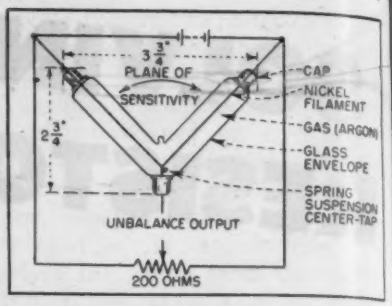


Convectron vertical position sensing tube made by Eclipse-Pioneer Div. of Bendix changes resistance of its two arms when displaced in the plane through its legs

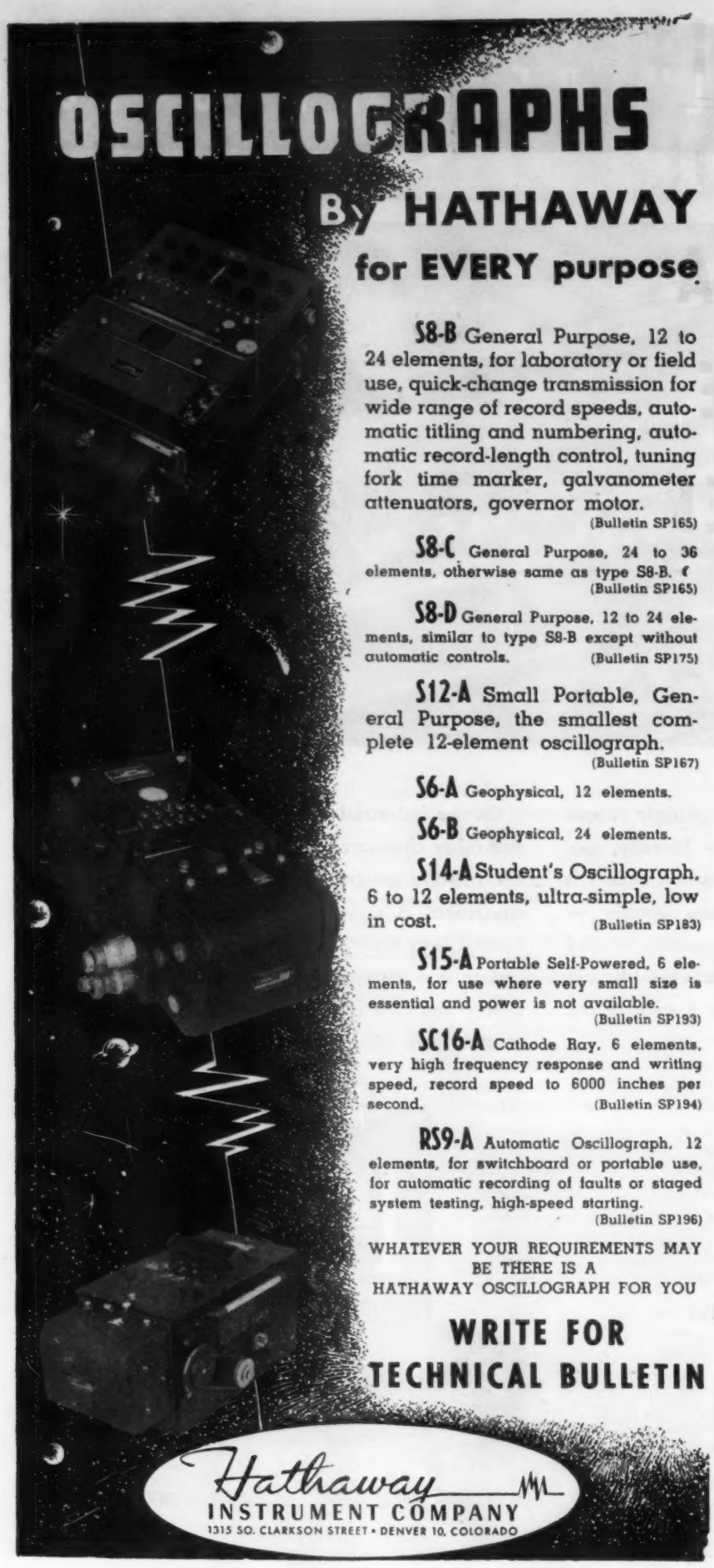
sensing element in positioning servomechanisms. It is simpler to mount than mechanical indicators, has no moving parts, and directly gives an electrical output.

Operating Characteristics

The tube and bridge circuit in which it can be used are shown in the diagram. The filament is heated by either alternating or direct current. It looses heat chiefly by gas convection. Because the gas convection currents rise vertically passing the filament at an angle dependent on the tube's orientation, the cooling of the two legs of the filament is different for different angular positions in the plane through the tube. The filament is made of nickel so that its resistance changes appreciably with temperature, thus, in a bridge circuit, these resistance changes upset the balance when the tube is displaced from its normal position.

Convection currents in the tube are caused by differences in mass between heated and cooled portions of the gas. As a vertical position indicator, these differences of mass react with the force of gravity to produce convection flow. However, if the tube is accelerating (linearly or rotationally), there is an acceleration force against which the differences of mass react to produce convection currents. Under this condition the tube will indicate displacement from the vector sum of the gravitational and accelerational forces. The Convectron can, consequently, be used as an accelerometer (but is insensitive during free fall).

In operation the filament is heated to an average of about 400 C. If a d-c source is used for the bridge, the unbalance output re-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verses polarity as the tube moves through its null position; if an a-c source is used, the output reverses phase. The tube thus senses direction as well as degree of displacement. Time constant of the tube is about 0.1 sec, and the displacement signal is about 50 millivolts per degree at null. Resistance is a function of operating voltage

Supply Emf in volts	Current in ma	Resistance in ohms
0	0	50
5	56	89
10	74	183
15	80	188

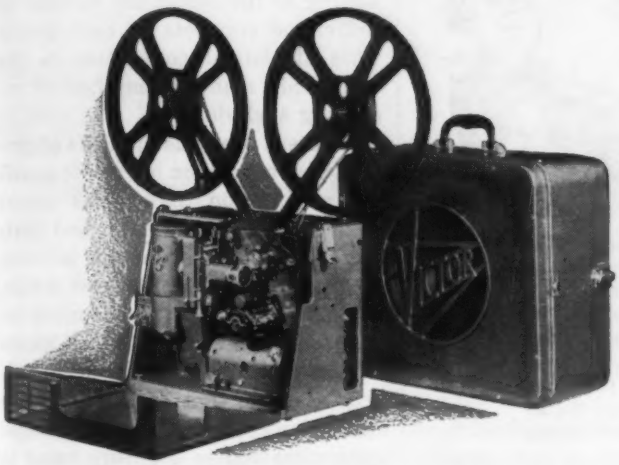
the tube being most sensitive with a supply of about 10 volts, at which voltage it draws less than a watt. With an a-c supply the noise level is between 1 and 5 millivolts, and is less for d-c supply. Using a d-c supply, displacements as small as one second of rotation can be detected. For such extreme sensitivity the null is affected by ambient temperature and supply voltage; random air currents striking the tube affect ambient temperature.

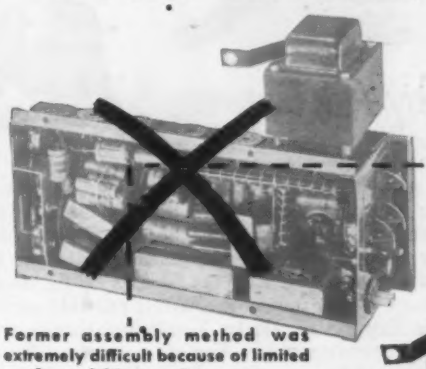
Statistical Methods Simplify Evaluation of Data

INTERPRETATION of many forms of data can best be done statistically. Although the usual approach to a series of measurements is to determine a simple mathematical equation that describes them (and can be considered an expression of the natural law governing the phenomena under study), it is frequently more realistic to approach the measurements from a statistical basis, recognizing the fact that there is a spread in the measurements for any one condition. (Quantum mechanics on which modern physics is based is predicated on this statistical approach.) How such a statistical analysis can be made is illustrated by the recently developed method of predicting sunspot activity in connection with forecasting radio propagation by the National Bureau of Standards, and by the technique of determining the specifications for and the evaluation of the terrain clearance indicator for

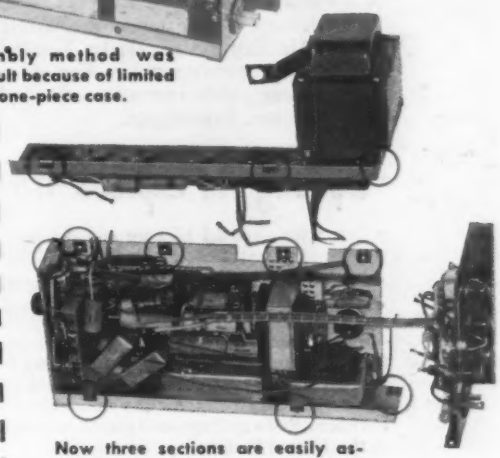
"WE DO FIND THAT WE HAVE REDUCED OUR ASSEMBLY COST APPROXIMATELY 36% ON THIS UNIT SINCE BEGINNING TO USE THE TINNERMAN SPEED NUT"

This is a direct quotation from a letter from A. S. Webeck, Works Manager of the Victor Animatograph Corporation, Davenport, Iowa, makers of 16 MM sound motion picture equipment.





Former assembly method was extremely difficult because of limited confines of this one-piece case.



Now three sections are easily assembled separately, and quickly fastened together with SPEED NUTS into completed unit.

SPEED NUTS always effect substantial savings in assembly cost, but here is a case of unusually high savings.

Victor Animatograph Corporation accepted our suggestions on the assembly of their amplifier unit. They discarded their time-consuming practice of assembling a myriad of small parts in a crowded case. Now the amplifier is assembled in three easy-to-get-at sections that are quickly fastened together with SPEED NUTS to complete the unit.

Assembler training time is cut from two months to a few hours. Assembly time is slashed, employee morale improved, and with three assembly lines instead of one, the risk of complete production stoppage due to shortage of one or two parts is avoided.

Let us demonstrate what SPEED NUTS can accomplish in improving the assembly of your product.

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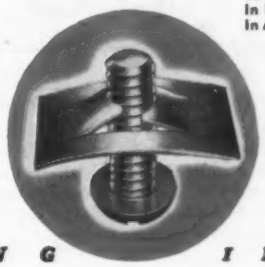

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anticollosion aircraft flying developed by Hughes Aircraft Co.

Predicting Sunspot Activity

Solar activity, which greatly affects radio communication, is evidenced by sunspots. The number and activity of the sunspots varies greatly over an 11-year period, indicating local variations in sun's temperature, and hence the relative intensity of radiation from the sun that in turn determines the condition of the earth's ionsphere. Basic information on sunspot numbers is obtained from the Zurich Observatory in Switzerland, which has made continuous records of solar activity since 1849, and from other observers. Sunspot number is obtained by counting the number of sunspot groups, multiplying by ten, and adding to the result the number of individual sunspots in each group. This statistical convention is the worldwide standard method of recording such data.

Whereas previous methods of prediction depended on harmonic analysis, assumption that cycles repeat after a number of years, and various empirical relationships between heights of maxima and rates of rise, the statistical method advanced by A. G. McNish and Virginia Lincoln of the National Bureau of Standards assumes that, in a time series exhibiting cyclical tendencies, a first approximation to a future value is the mean of all past values at the same stage of the cycle, and that this first approximation can be improved by adding to the mean a correction proportional to the departure of earlier values of the same cycle from their respective means. The second assumption is justified by the observed tendency in sunspot numbers from annual deviations from the mean to have the same sign and similar magnitudes in con-

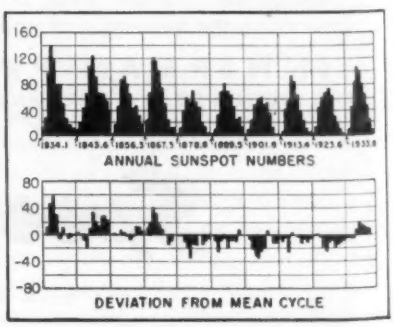
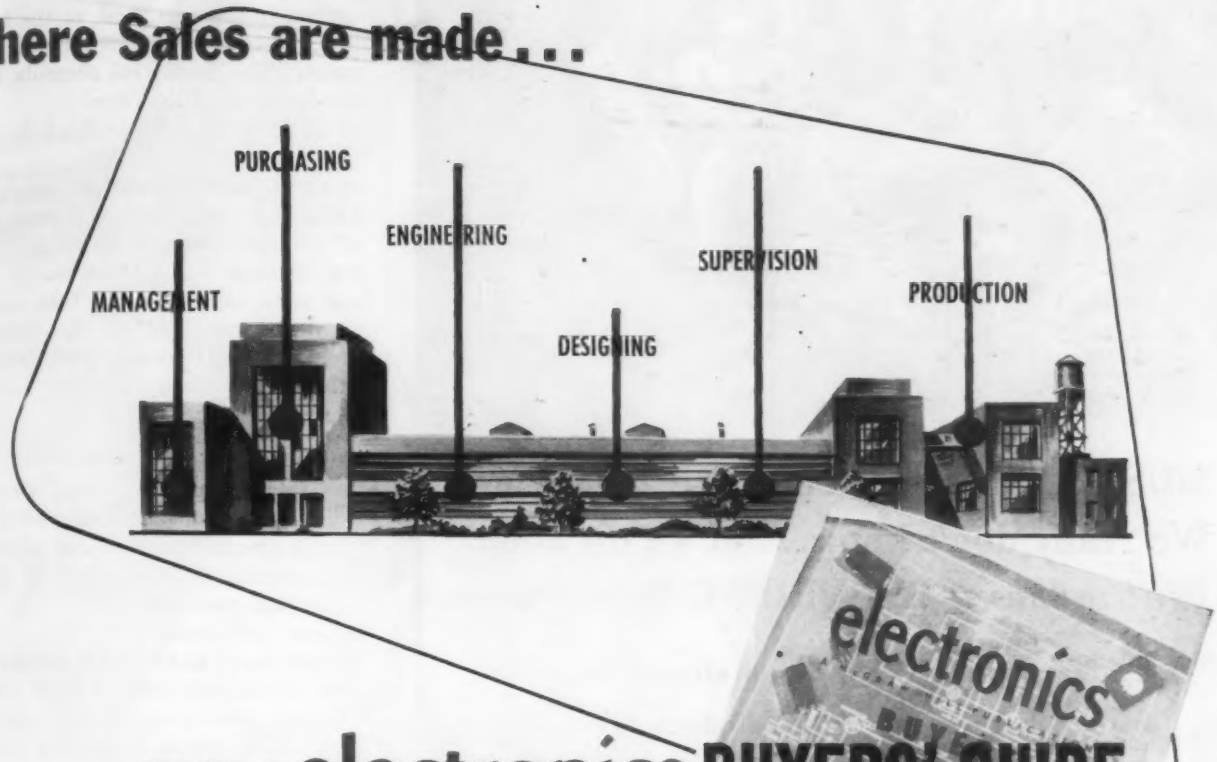


FIG. 1—Sunspots from 1834 to 1944

Where Sales are made . . .



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Over a million Soundcraft discs have now been delivered to broadcasting chains, individual stations, motion picture studios, sound studios, phonograph record companies, educational institutions and home recordists. This cross section of the industry, moreover, demands Soundcraft discs day after day. *And* the most critical users are the most insistent upon Soundcraft.

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Soundcraft

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secutive years. Figure 1 shows, at the top, the sunspot numbers recorded in the past, and, at the bottom, the deviation from the cyclic mean. The prediction formula for the future is of the form

$$R_n' = R_n + k_{n-2}\,\Delta R_{n-1} + k_{n-2}\,\Delta R_{n-2} + \ldots$$

where R_n' is the predicted value in a particular cycle, R_n is the mean of all corresponding values in preceding cycles, $\Delta R_{n-1}'$ is the deviation of the particular R_{n-1} for this cycle from the mean of all R_{n-1} values from previous cycles, and the k values are proportionality constants.

• *Probability of Aircraft Collision*

Airplane collisions with mountains have always constituted one of the spectacular hazards of airline operation. Statistical studies of terrain contours in the vicinity of principal airways over mountainous territory, and of CAA and CBA terrain collision reports from 1933 to 1946, have revealed two significant facts. Most accidents took place within 500 feet of the summit of the obstacle. Secondly, the profiles are such that if planes approaching peaks are given warning of terrain clearance of 2,000 feet (by a radio altimeter for example), the pilot could rise clear of the mountain by a routine evasive action of continuing in a straight course but climbing 900 feet in the first mile after clearance warning and continuing to climb at 500 feet a mile until the plane had climbed 2,000 feet or enough higher so that the warning signal disappears. This maneuver is readily executed at sustained power by most transports. Figure 2 shows a typical profile and how the evasive maneuver would avoid a collision. From these profiles it was found that pilots would be warned of flying too low on a weighted average of 7.5 miles from the peak, and in extreme cases only within 3 miles or as far away as 30 miles. The collision records (and normal expectations) indicate that pilots are more often flying close to the peak altitude than well below it. However, planes might attack at any altitude. Therefore, a weighting (that is conservative, judged by actual records) was assigned each 500-foot altitude interval; assuming that, of all the planes that might

Television buyers expect a lot...

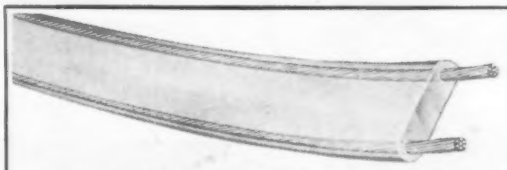
...ATV helps deliver

"It is interesting to note," writes Dan Halpin, RCA Victor Television Sales Manager, that this new kind of transmission line (ATV*), now widely used in television transmission between the antenna on a customer's roof and a receiver installed in the home, is identical with the line developed for wartime radar use, and which had to stand severe temperature changes and unusual climatic conditions.

"It is many times more efficient than any prewar line and is playing a large part in the success we are enjoying with RCA Victor television. By the end of this year television should serve approximately 35% of our nation's wired homes."

The well balanced design of conductors and dielectric in Anaconda Type ATV lead-in lines fulfills the exacting requirements of wide-band reception. For FM and television reception, these lead-in lines minimize the effects of attenuation and impedance mismatch—providing maximum freedom from distortion.

No wonder manufacturers are enthusiastic about ATV! Television buyers expect a lot and ATV helps to deliver.



Anaconda offers to the industry a wide selection of Type ATV lead-in lines for 75, 125, 150 and 300 ohms impedance unshielded and 150 ohms shielded—each designed for a particular application. Anaconda also manufactures a complete line of coaxial cables. For characteristics of these products, write to Anaconda Wire and Cable Company, 25 Broadway, New York 4, New York.

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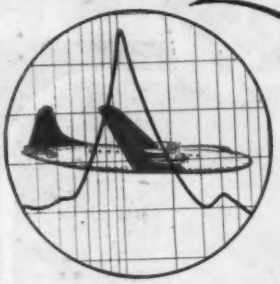

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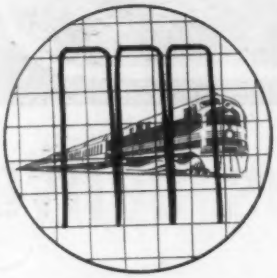

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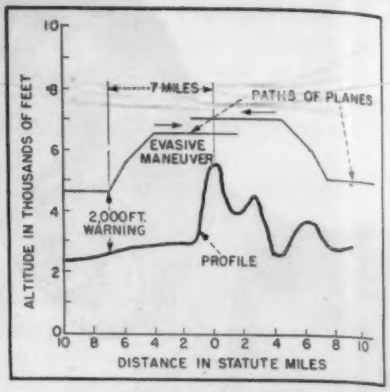

FIG. 2—Typical terrain profile

crash into a mountain side, five would be in the 500-foot level just below the peak, four in the next lower level, and so on with one plane each in all the very low levels. On this basis a 1,000-foot terrain clearance warning would avert 82 percent of all hypothetical crashes, and a 2,000-foot warning would avert 96 percent of them. In the east, where mountainous terrain is less rugged, a 500-foot warning would be sufficient to avert most accidents. On this basis a simple terrain clearance radar with a 2,000-foot and a 500-foot range that has been recently publicised was adopted for commercial use.

In the case of sunspot prediction, the analysis assures that, although the forecast will not be exactly correct, it will indicate the most likely condition. In providing anticollision radar, it would be difficult to determine the required range and predict the probable reliability of any specified radar without resorting to statistical analysis. Many engineering problems involving gross phenomena (sunspots and the like) or many variables and probabilities (terrain clearance) can be best solved by such statistical approaches as these.

Myographs

BY W. E. GILSON
Department of Medical Electronics

J. A. E. EYSTER
Department of Physiology
The University of Wisconsin Medical School
Madison, Wis.

IN STUDYING the sequence of heart action of the dog and the turtle, particular interest was centered on the fractionate contraction occur-

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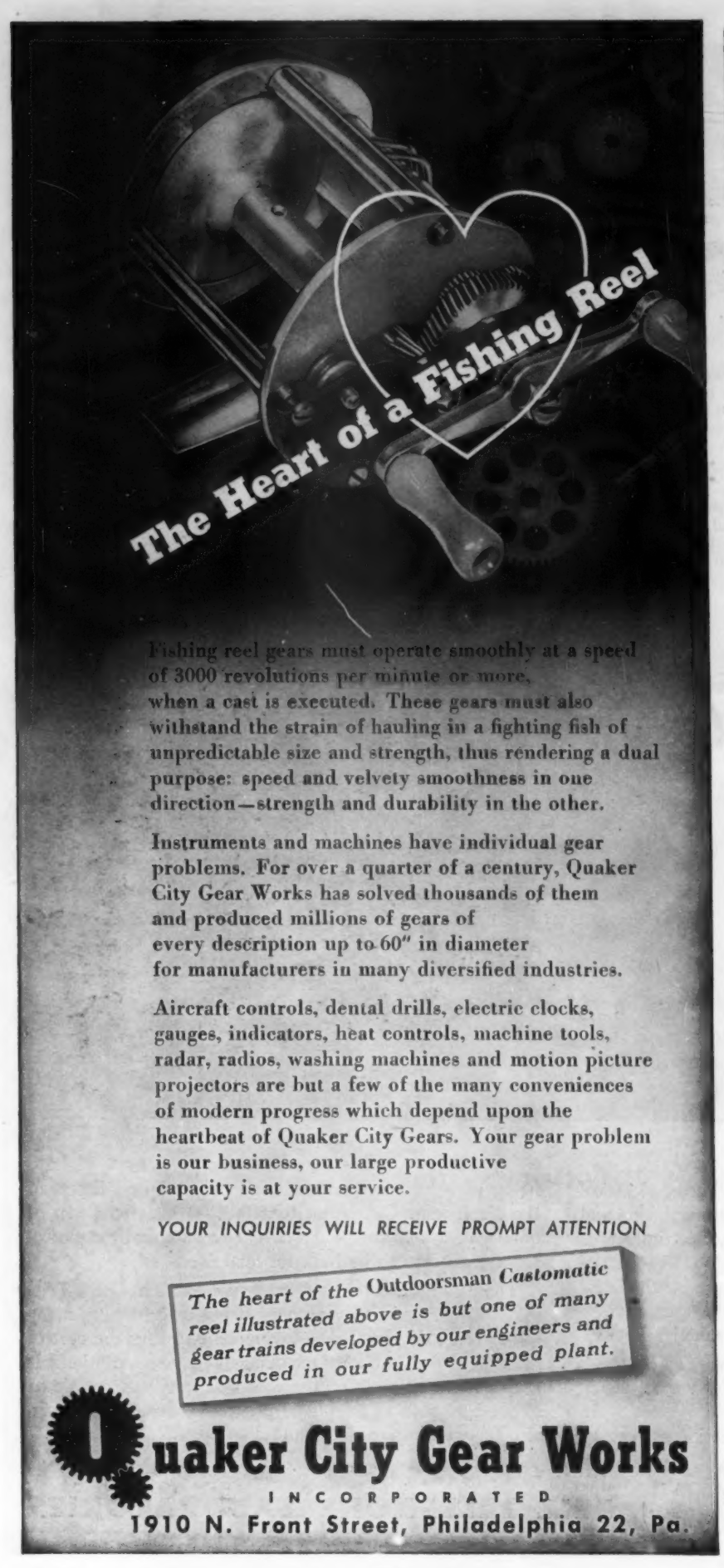

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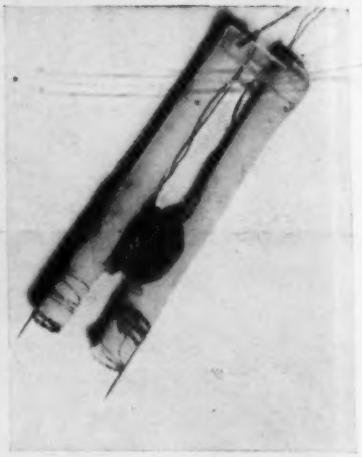


FIG. 1—Variable-inductance myograph has supporting columns made of 5-cm lengths of soda straw. Points are usually so spaced on specimens that coils are 2 to 3 mm apart

ring at the onset of a complete contraction cycle. To observe this effect, it was necessary to construct a myograph, an instrument to measure displacement or velocity of muscular contraction.

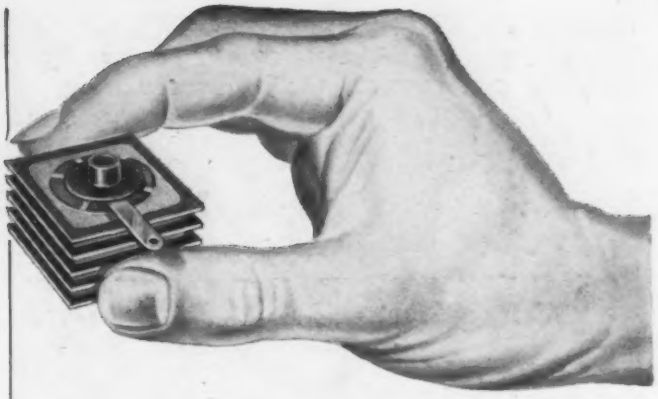
It was assumed that the onset of contraction was signalled by the coming together of two closely spaced points on the surface of the heart. Consequently, the basic myograph element was a light frame, rather like a drafting divider, whose points rested on the surface of the heart and were drawn together as fractionate contraction occurred.

Overcoming Inadequacies

To record precisely the onset of contraction with the least possible time lag, the myograph had to have small inertia. In addition, the instrument had to rest lightly on the heart and be capable of being actuated by a very small force. Several myographs were constructed which proved less satisfactory than the variable-inductance unit finally developed.

The first unit constructed was based on a capacitance principle. Two insulated plates, forming a variable capacitance, were mounted on the arms of the myograph so that the capacitance increased when the points came together. This capacitor was connected across the tank circuit of a variable-frequency oscillator, working at approximately 456 kc. The output of the oscillator was detected after passing

need a mite



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through a 456 kc i-f transformer. The frequency of the oscillator was set so that it came in the middle of the sloping side of the response characteristic of the transformer. Thus the d-c output of the detector was a direct function of the capacitance of the myograph. An alternative method used the same myograph in a bridge circuit.

Curves were obtained with this myograph measuring fractionate contraction of the turtle venticle. These curves, however, indicated that the entire heart contracted simultaneously, which did not agree with other data obtained from the same animal. The myograph was then tested by tying its points together and placing it on the heart. The same type of curve was obtained as before, showing that the effect of the varying capacitance to the body with movement of the heart practically obliterated the curve of local contraction.

A second instrument was then built, in which the plates were completely shielded from external changes of capacitance, and a shielded lead was used to connect to the plates. This model worked considerably better, but was still not satisfactory, because when the points were tied together and the myograph placed on the turtle heart, a small curve was still obtained. This curve was found to be caused by a change in the capacitance of the shielded lead even with slight bending.

Satisfactory Types

The third type of myograph[1] was considerably more satisfactory. It consisted of two pieces of filter paper wet with salt solution, mounted in a V on the arms of the myograph, so arranged that when the points were brought together, the V would shorten, decreasing its resistance. This variable resistance was placed in a bridge circuit energized by a 50,000-cycle oscillator to eliminate polarization. The output of the bridge was rectified and connected to the recording mechanism.

Many excellent records were obtained with this device, but it was still not altogether satisfactory as there was drift of the reference

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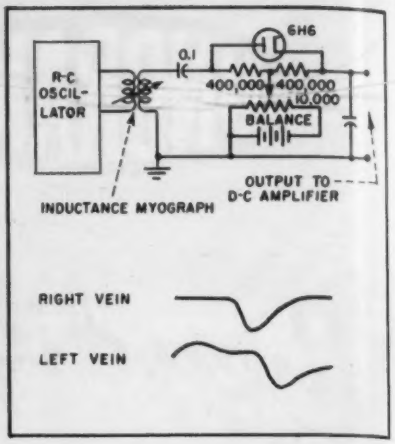

FIG. 2 — Two variable-inductance myographs, of the type shown in the schematic diagram, were used to make this record of fractionate contraction of the veins going to a turtle heart

line with evaporation of the salt solution. In addition there was a theoretical possibility of a variable lag due to surface tension of the solution.

Another myograph was then constructed which utilized the photoelectric principle. A very small photocell and a bronchoscope light were mounted on one arm of the myograph so that the light projected directly onto the photocell. A shutter extended from the other arm, cutting off the light as the points were brought together by contraction. This was satisfactory, except that it was too heavy for practical use in many circumstances[3].

The instrument in use at present is of the inductance type. One coil is mounted on each of the arms which are so arranged that they are almost in contact when the points are separated by about 3 mm. The coils of No. 41 wire are wound on extremely light plastic forms about 1 mm thick and 11 mm in diameter. One is energized by 50,000-cycle current from an R-C oscillator. The other coil acts as the secondary of a transformer, and produces a voltage of varying magnitude, depending on the separation of the coils. The output of the secondary coil is rectified and fed to the recording apparatus as varying d-c. The myograph is shown in Fig. 1. This instrument is sufficiently sensitive so that it can be used for recording the fractionate contraction of the veins going to

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the turtle heart. A schematic circuit diagram of the myograph together with a record obtained using two instruments of this type are shown in Fig. 2.

This research was supported in part by the Wisconsin Alumni Research Foundation and the Brittingham Research Fund.

(1) H. Goldberg and J. A. E. Eyster, *Am. J. Physiol.*, p 390, *Vol.* 128, 1940.
(2) W. E. Gilson, Applications of Electronics to Physiology, ELECTRONICS, Jan. 1943.

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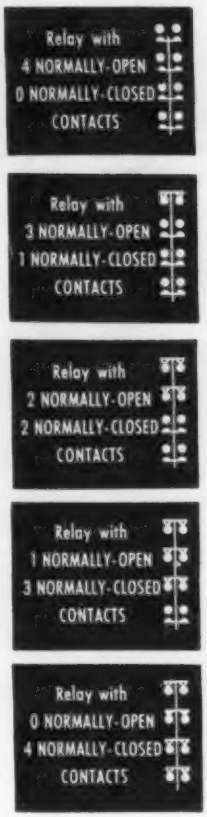

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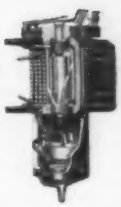

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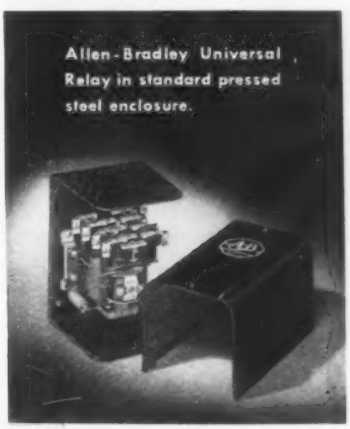

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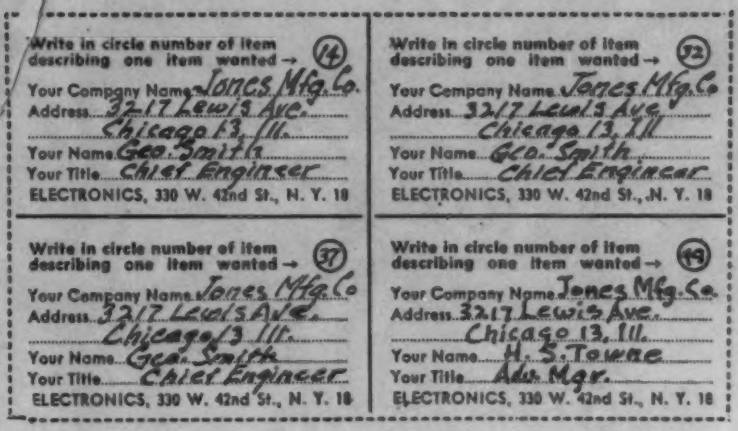
LITERATURE and NEW PRODUCTS

Manufacturers' Literature as well as further information on New Products described in this issue are important "working tools" for design and production departments. To make it easy to keep up to date, ELECTRONICS will request manufacturers to send re[turn] the literature in which they [are] interested. Just fill out card as shown in the filled-in sample (right), being particularly careful to write out in full all the information called for in each section of each card that is used.



SAMPLE CARD SHOWING CORRECT FILL-IN ←

HOW TO ORDER:

1. There are two postcards, each divided into four parts. Each of the four parts contains a ◯. You must write in this ◯ the number that appears in this issue over the literature or new product item in which you are interested. Place one number only in each circle.

2. Fill out completely (name, address, etc.) for each piece of literature or new product information you desire.

Do *not* say "same" in lieu of writing out full information called for when requesting more than one item.

3. This service applies only to literature and new product items in this issue. It does not apply to advertisements. Write directly to the company for information on its advertisements.

PLEASE NOTE: Requests for unnumbered items must be made direct to the manufacturer.

In the event this copy of ELECTRONICS is passed along to other members of your company, please leave this sheet in for their convenience. This assures everyone in your plant the opportunity to fill in their requests. When the round is completed, cards can then be detached along perforated lines and dropped in the mail. Each individual request will be mailed by us to the company offering the information and for that reason must be completely filled out.

PLACE 1¢ STAMP ON CARD • DO NOT USE AFTER FEBRUARY 1

Write in circle number of item describing one item wanted → ◯

Your Company Name.....

Address.....

.....

Your Name.....

Your Title.....

ELECTRONICS, 330 W. 42nd St., New York 18, N. Y.

Write in circle number of item describing one item wanted → ◯

Your Company Name.....

Address.....

.....

Your Name.....

Your Title.....

ELECTRONICS, 330 W. 42nd St., New York 18, N. Y.

Write in circle number of item describing one item wanted → ◯

Your Company Name.....

Address.....

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Your Name.....

Your Title.....

ELECTRONICS, 330 W. 42nd St., New York 18, N. Y.

Write in circle number of item describing one item wanted → ◯

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Your Title.....

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Write in circle number of item describing one item wanted → ◯

Your Company Name.....

Address.....

.....

Your Name.....

Your Title.....

ELECTRONICS, 330 W. 42nd St., New York 18, N. Y.

Whether

RADIO AMPLIFIER or QUANTOMETER

PHOTO COURTESY RADIO STATION WOR & WESTERN ELECTRIC

Cannon Electric Type DPB Connector using gold-plated contacts in Studio Control Booth Console, Type 120 Amplifier in the low level side. Plug-in connector greatly increases ease of servicing and maintenance.

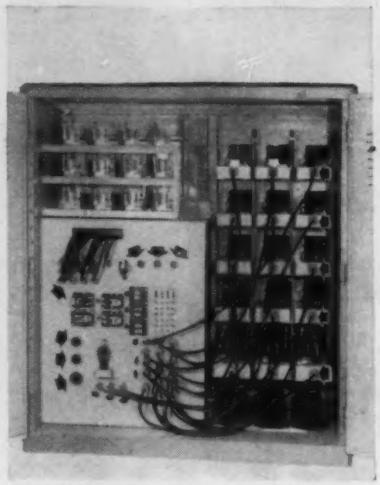


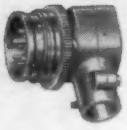
PHOTO COURTESY APPLIED RESEARCH LAB., GLENDALE, CALIF.

Arrows point to Cannon Electric Type "K" fittings connecting a maze of circuits on the Quantometer, a direct-reading spectometer which determines chemical analysis of metals in 45 seconds. Rear view shown.

Plug-in with

CANNON PLUGS

K-21 Plug



RK-24C Plug

TYPE "K"—made in 3 general shell types with nearly 190 insert arrangements available for a wide variety of wire sizes, including coaxials.

TYPE DPB—rack type pin and socket assemblies (both for fixed mounting) carry standard, coaxial and twinax contacts. Six basic lay-outs available in DPB, many more in the larger DPD shell size.

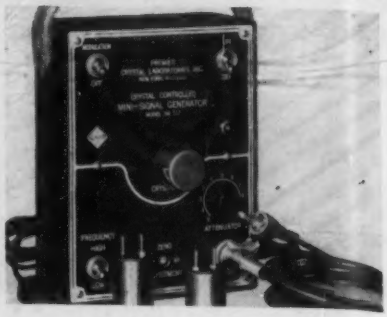
NEW EDITION C-46-A CATALOG—For a complete survey of the majority of Cannon Electric products, send for this C-46-A Catalog, containing prices on many items. Also included are the names and addresses of our distributors. Write Department K-120.

CANNON ELECTRIC

CANNON ELECTRIC DEVELOPMENT COMPANY

3209 Humboldt Street, Los Angeles 31, California

Canada & British Empire — Cannon Electric Co., Ltd., Toronto, Ontario • World Export Agents (excepting British Empire) Frazar & Hansen, 301 Clay St., San Francisco 11, Calif.



draws 17 watts, and comes equipped with a 6-foot cord and 53-inch leads with insulated clips.

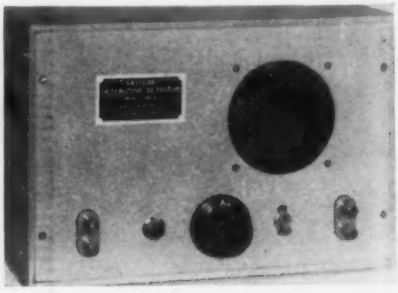
• Calibration Units (16)

JAMES MILLEN MFG. CO., INC., 150 Exchange St., Malden 48, Mass., announces two new frequency calibration units for use in checking trans-

mitter carrier frequencies and other h-f signals against WWV. Model 90515 combines the functions of the secondary frequency standard model 90505 and the h-f multiple and mixer unit, model 90511. Model 90511 is also available separately.

Heterodyne Detector (17)

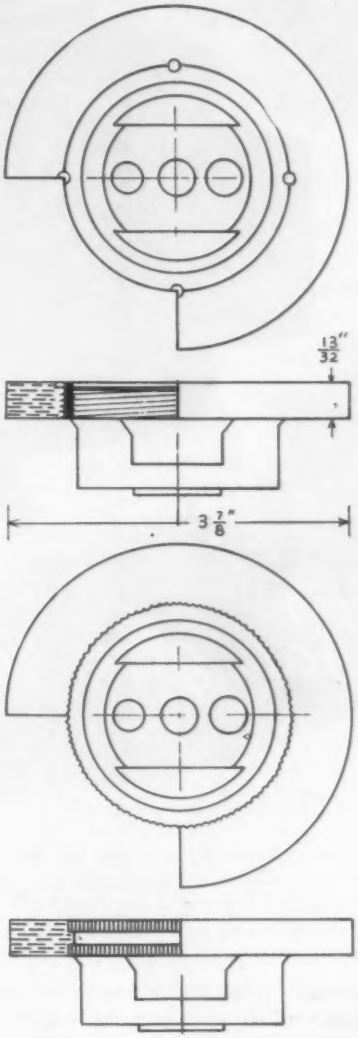
KALBFELL LABORATORIES, INC., 1076 Morena Blvd., San Diego 10, Calif. The Kay-Lab heterodyne detector will measure signals of 100 microvolts and is usable from 500 cycles to 50 mc. It is used to compare an



Problems solved by Richardson...in Plastics

#2 - DESIGN OF A PLASTIC AIRCRAFT GEAR

PROBLEM: MAGNETO GEAR AS ORIGINALLY DESIGNED WAS A DISK OF INSUROK LAMINATED MATERIAL. BORED & THREADED ON THE INSIDE DIAMETER, & SCREWED ONTO A METAL SPIDER. AFTER WHICH, HOLES WERE DRILLED THROUGH THREADED SECTIONS, INTO WHICH METAL PINS WERE DRIVEN & RIVETED. THIS METHOD OF ASSEMBLY PROVED INEFFICIENT DUE TO THE STRENUOUS STRESSES REQUIRED FOR AIRCRAFT, & DISKS HAD TENDENCY TO LOOSEN. THUS THE PROBLEM WAS TO SECURE A PERMANENT MOUNTING WHICH COULDN'T BE LOOSENED FROM THE SPIDER.



SOLUTION: RICHARDSON PLASTICIANS RECOMMENDED ADOPTION OF MOLDED PROCEDURE. INSTEAD OF THREADING THE SPIDER, THIS SECTION WAS DEEPLY KNURLED & A CENTRAL GROOVED RECESS WAS CUT AFTER KNURLING. THE SPIDER WAS MOUNTED IN A SUITABLE MOLD & DISKS OF SATURATED MATERIALS WERE MOLDED INTO PLACE. MATERIAL FILLED RECESS & KNURLED PORTIONS TO GIVE PERFECT BONDING.

WHEN ELECTRICAL FLASH-OVERS OCCURRED AT LATER DATE, MOLD WAS CHANGED TO PERMIT INCLUSION OF SATURATED DISKS TO COVER METAL WHERE FLASH-OVERS OCCURRED. THIS DESIGN CHANGE ELIMINATED ALL PREVIOUS DIFFICULTIES.

INSUROK *Precision Plastics*

INSUROK is the family name of a great variety of laminated and molded plastic products produced by Richardson. Laminated INSUROK is available in sheets, rods, tubes, punched and machined parts, made with paper, fabric, glass, etc. Molded INSUROK products are made from Beetle, Bakelite, Plaskon, Tenite, Styron, Durez, Lucite, etc., by compression, injection and transfer molding.

The RICHARDSON COMPANY

Sales Headquarters: MELROSE PARK, ILL. FOUNDED 1858 LOCKLAND, CINCINNATI 15, OHIO

Sales Offices

NEW YORK 6, 75 WEST STREET
PHILADELPHIA 40, PA., 3728 NO. BROAD STREET
CLEVELAND 15, OHIO, 326-7 PLYMOUTH BLDG. • DETROIT 2, MICH., 6-252 G. M. BLDG. • ROCHESTER 4, N. Y., 1031 SIBLEY TOWER BLDG.
MILWAUKEE 3, WIS., 743 NO. FOURTH STREET
ST. LOUIS 12, MO., 5579 PERSHING AVENUE
INDIANAPOLIS, IND.

Factories: MELROSE PARK, ILL. • NEW BRUNSWICK, N. J. •

RICHARDSON MEANS *Versatility* IN PLASTICS

An electronics service designed for READERS and MANUFACTURERS

FOR THE READER... ELECTRONICS fundamental policy has always been to supply its readers with all the pertinent and timely industry news. The ELECTRONICS Reader Service supplements this policy by offering the reader an easy and effective means of obtaining complete, up to the minute data on new products and of maintaining at his fingertips comprehensive, practicable information on "who's doing what" in the industry.

In every issue of ELECTRONICS there's complete coverage of the month by month development by manufacturers of new materials, components and equipment, as well as brief mention of all the important, new, manufacturers' technical pamphlets and catalogs. Some of these items will be of particular interest to specific design and plant engineers, buyers, executives and others of our readers. They will want to make further inquiry concerning the new products described or they will want to read and make a permanent part of their industrial library some of the manufacturers' literature and catalogs. ELECTRONICS Reader Service makes it easy for them to obtain in readily accessible and usable form the information they desire.

PLACE 1¢ STAMP ON CARD • DO NOT USE AFTER FEBRUARY 1

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ELECTRONICS

330 WEST 42nd STREET

NEW YORK 18, N. Y.

11-1-47

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ELECTRONICS

330 WEST 42nd STREET

NEW YORK 18, N. Y.

11-1-47

FOR THE MANUFACTURER...

ELECTRONICS Reader Service will also be welcomed by manufacturers who are desirous of placing the complete news of their product developments as well as their technical bulletins and catalogs in the hands of those members of the electronic industry . . . including design, electrical and production engineers, researchers, physicists, executives, and buyers —who have a particular interest in, or represent a potential buying power for, their products.

SUGGESTIONS FOR THE IMPROVEMENT OF OUR READERS' SERVICE ARE INVITED

ELECTRONICS is constantly seeking new and improved ways of providing its readers with the news and information they want and need, and of assisting the manufacturer in effectively delivering his message to electronic markets. If you have any ideas for us, send them along. They will receive prompt consideration.

The unique differences in the design of an electronic product often call for components that are slightly different than so-called standard. Here is an Acme Electric transformer which may give expansion to your ideas — to take advantage of all the "extras" for better performance.

We call this "Mounting Type 130" — two hole horizontal mounting, with lead holes on bottom or side of shell. It is developed in ratings from 15 VA to 100 VA to the exact electrical characteristics that you require. Made from standard parts to special specifications and produced by straight line volume production methods. For further details, write for Bulletin 168, or better still, tell Acme Electric transformer engineers about your problems and let them assist you.

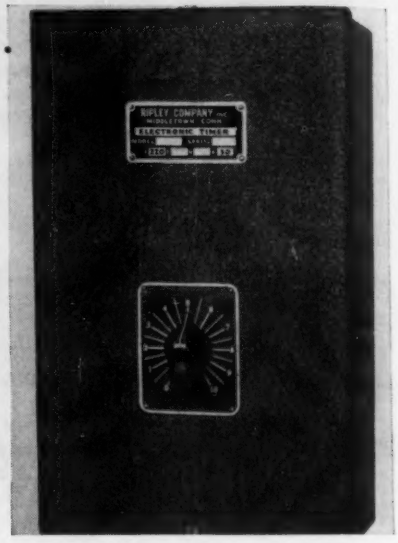
ACME ELECTRIC CORPORATION
31 Water St. CUBA, N. Y.

Acme ACME Electric

unknown frequency with that of a signal generator. In addition it will demodulate an a-m signal without use of a second oscillator. The circuit consists of a pentagrid converter and a high-gain audio amplifier with loudspeaker.

Welding Timer (18)

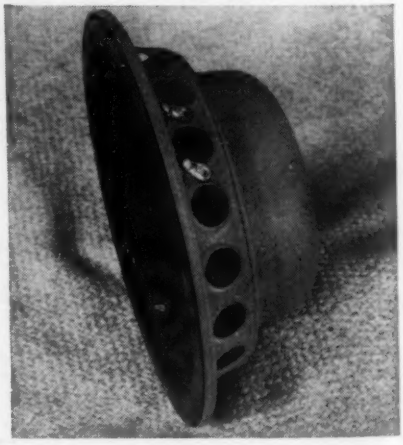
RIPLEY CO., INC., Middletown, Conn. The 52D Timatron can time any welding machine up to 10 kva and is adjustable from 0.1 second to 5 seconds by a hand control covering



any timing range desired. Once set for a particular thickness of metal, timing becomes automatic for the entire production run.

Loudspeaker (19)

GRAYBAR ELECTRIC CO., 420 Lexington Ave., New York 17, N. Y. Western Electric type 755A loudspeaker is an 8-inch unit with a frequency



WHAT MAKES A MAILING CLICK?

Advertising men agree—the list is more than half the story.

McGraw-Hill Mailing Lists, used by leading manufacturers and industrial service organizations, direct your advertising and sales promotional efforts to key purchasing power. They offer thorough horizontal and vertical coverage of major markets, including new personnel and plants. Selections may be made to fit your own special requirements.

New names are added to every McGraw-Hill list daily. List revisions are made on a twenty-four hour basis. And all names are guaranteed accurate within two per cent.

In view of present day difficulties in maintaining your own mailing lists, this efficient personalized service is particularly important in securing the comprehensive market coverage you need and want. Ask for more detailed information today. You'll probably be surprised at the low over-all cost and the tested effectiveness of these hand-picked selections.

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DIRECT MAIL LIST SERVICE

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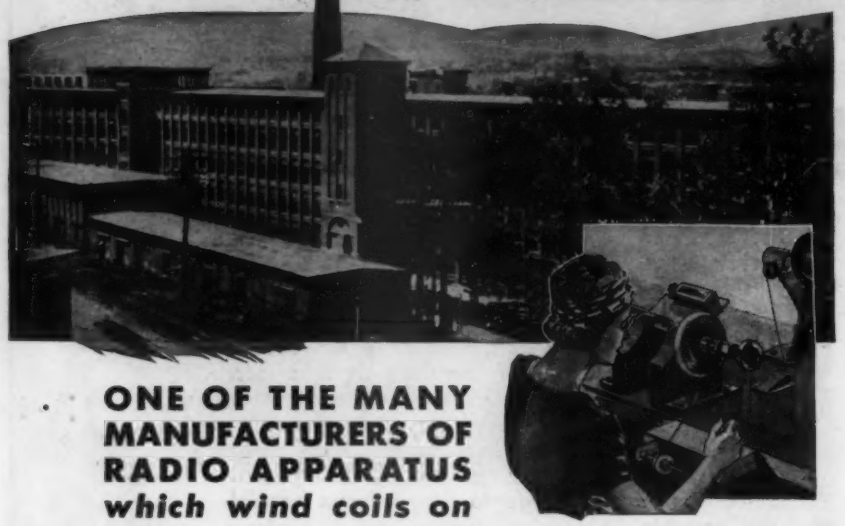
MAIL
DIVISION

McGraw-Hill Publishing Company, Inc.
330 West 42nd Street New York, N.Y.

Factory View

The F. W. SICKLES COMPANY
OF CHICOPEE, MASS.
LEADING MANUFACTURERS OF
RADIO ELECTRICAL APPARATUS



ONE OF THE MANY MANUFACTURERS OF RADIO APPARATUS *which wind coils on*

COSMALITE* forms

The Cleveland Container Company recommends for YOUR consideration these spirally laminated paper base, Phenolic Tubes.

Wall thicknesses, diameters, punching and notching to meet your individual needs.

WE RECOMMEND our #96 COSMALITE for coil forms in all standard broadcast receiving sets; our SLF COSMALITE for permeability tuners.

Spirally wound kraft and fish paper Coil Forms and Condenser Tubes.

• •

Inquiries welcomed also on COSMALITE COIL FORMS for Television Receivers.

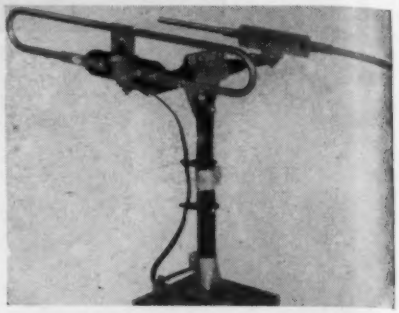
*Trade Mark Registered

The CLEVELAND CONTAINER Co.
6201 BARBERTON AVE. CLEVELAND 2, OHIO
• All-Fibre Cans • Combination Metal and Paper Cans
• Spirally Wound Tubes and Cores for all Purposes
• Plastic and Combination Paper and Plastic Items
★ ★ ★
PRODUCTION PLANTS also at Plymouth, Wisc., Ogdensburg, N. Y., Chicago, Ill., Detroit, Mich., Jamesburg, N. J.
PLASTICS DIVISIONS at Plymouth, Wisc., Ogdensburg, N. Y. • ABRASIVE DIVISION at Cleveland, Ohio
SALES OFFICES — Room 223, 1186 Broadway, N.Y.C., also 647 Main St., Hartford, Conn.
IN CANADA — The Cleveland Container Canada Ltd., Prescott, Ontario.

response from 60 to 13,000 cycles. With 8 watts output, the speaker is only 3½ inches deep and requires a baffling enclosure of only two cubic feet.

F-M and Television Antennas (20)

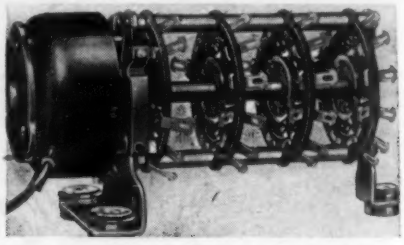
WARD PRODUCTS CORP., 1523 E. 45th St., Cleveland 3, Ohio, is now producing a line of Magic Wand dipole



f-m and television antennas. Included are a choice of straight or folded dipoles for both the 88- to 108-mc f-m band and the 44- to 88-mc television band.

Solenoid-Operated Switch (21)

G. H. LELAND, INC., 116 Webster St., Dayton 2, Ohio, announces a new circuit selector switch, the rotor of which is driven by a solenoid. The solenoid operates on d-c



and the unit can be incorporated in many appliances employing selection of electrical control circuits. Typical application is for an automobile radio.

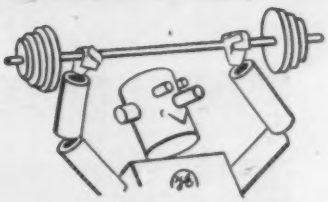
Ceramic Form (22)

HENRY L. CROWLEY & CO., INC., 1 Central Ave., West Orange, N. J. A new universal ceramic coil form eliminates the need for special holes to take leads or mount terminals. The fluted coil form has dovetail grooves that allow taking a tap lead which can be passed down under the

USE G-E MYCALEX INSULATION

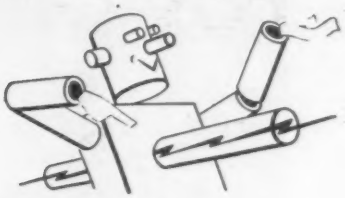
For a FIRM BOND TO METAL INSERTS...

Plus these 5 Insulation Advantages...

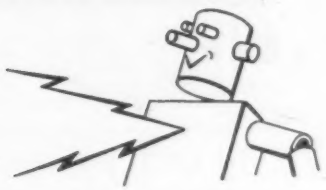


• HIGH MECHANICAL STRENGTH

• HIGH DIELECTRIC STRENGTH



• LOW LOSS FACTOR



• HIGH ARC RESISTANCE

• HIGH HEAT RESISTANCE

●General Electric mycalex is an exceptional insulation material because of its unique combination of properties. Use G-E mycalex when insulator designs call for inserts to be firmly molded in the insulation—*plus* excellent resistance to heat and arcing, high dielectric and mechanical strength, and a low loss factor. G-E mycalex is a gray, stone-hard compound of glass and mica that can be ordered in standard rods and sheets, or molded or fabricated to your specifications. Samples supplied on request.

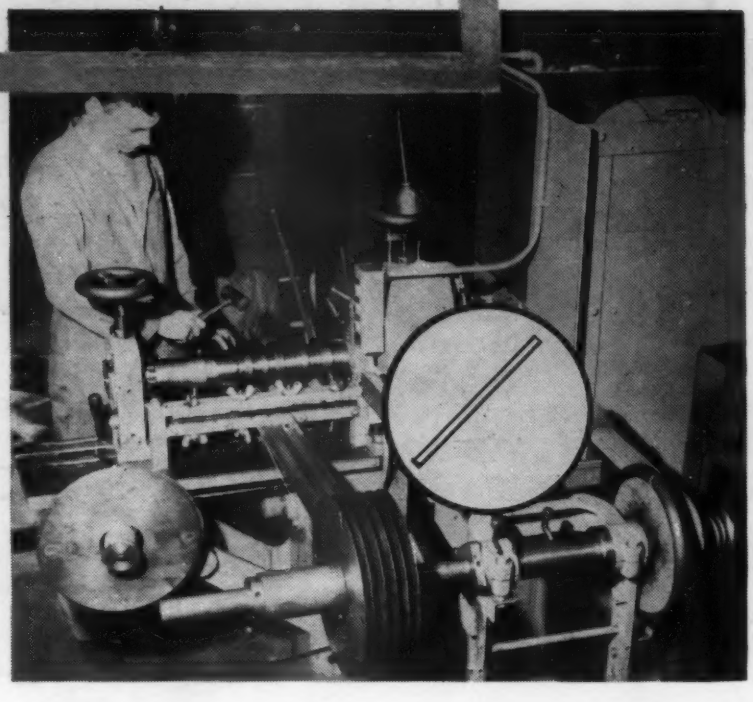
General Electric has complete molding and fabricating facilities for producing G-E mycalex parts in any quantity. Let General Electric's mycalex specialists fabricate sample parts for you to test. After testing, your designs can be converted to the speediest, most economical molding processes. To get the complete story, send for the new booklet, "G-E MYCALEX." Write to Section S-22, Plastics Division, Chemical Department, General Electric Company, 1 Plastics Avenue, Pittsfield, Mass.

GENERAL ELECTRIC

CD-47-M22

MYCALEX

short cut to the impossible!



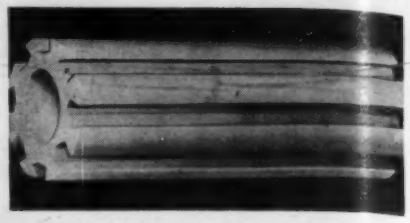
In manufacturing an electrical connector, BURNDY ENGINEERING required Silfos for a brazing operation. The problem was slitting .005" thick Silfos rolls to a width of 1/16". Only Eastern's specially modified slitters were able to do the job, *and with a tolerance of ± .00025"*.

The next time you need non-ferrous metals to meet your fabrication needs, try Eastern Brass and Copper Co., Inc. — "The Complete Source".

- Normal inventory of over 10,000 items of phosphor bronze, nickel silver, aluminum, brass and copper in all shapes, sizes and tempers.
- Immediate, efficient service to all points.
- The most complete processing facilities in the industry.

Inquiries invited from manufacturers. Write for our free 100-page catalogue and handbook of aluminum, brass and copper alloys.

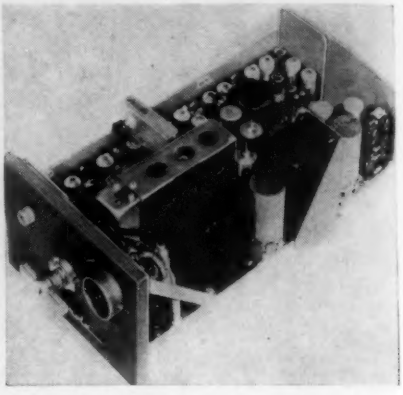
EASTERN BRASS & COPPER CO., Inc.
1121 LEBANON STREET, NEW YORK 60 • TALMADGE 3-2000
Precision Perfect • Slitting • Shearing • Rolling • Flattening • Annealing



turns to either end, or fastening a spring clip in the groove. The form is easy to mount or equip for iron-core tuning.

157-Mc Communicator (23)

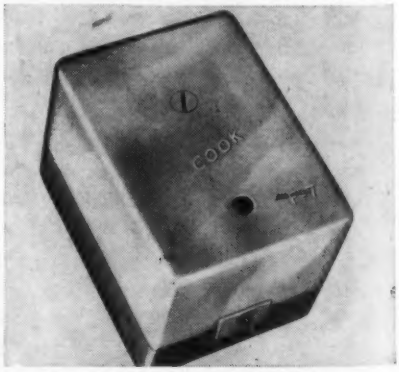
MOTOROLA, INC., 4545 W. Augusta, Chicago 51, Ill. The Dispatcher is a compact f-m radiotelephone transmitter and receiver for mobile service in the 152 to 162 megacycle band. It will sell for $397.50. Power



output is from 7 to 10 watts for a total transmitter drain of 20 amperes and a transmitter-receiver standby of 9.2 amperes. Full details of this equipment are available from the manufacturer.

Record Cutter (24)

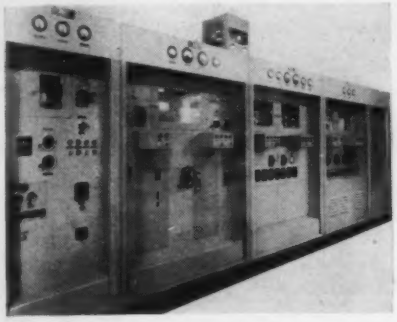
COOK LABORATORIES, 139 Gordon Blvd., Floral Park, N. Y. The model 5-A lateral recording system combines the cutter illustrated and a



50-watt amplifier that provides a stable high-frequency response and low intermodulation distortion. More than 30 db feedback is used. A switch located on the amplifier allows a selection of any of the three usual recording frequency characteristics.

Shortwave Transmitter (25)

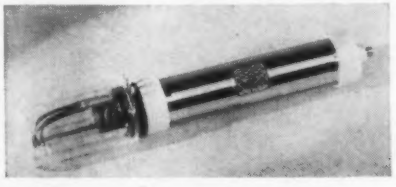
J. H. BUNNELL & Co., 81 Prospect St., Brooklyn 1, N. Y. Intended for international broadcast and communications service, the 20-kw



transmitter illustrated features front-panel continuous tuning over its entire frequency range from 2.85 to 22.5 mc.

Linear Acceleration Transmitter (26)

G. M. GIANNINI & Co., INC., 285 West Colorado St., Pasadena 1, Calif. The linear acceleration transmitter illustrated has an output proportional to longitudinal



acceleration, but is highly insensitive to quadrature accelerations. Ranges up to plus or minus 25 g are stocked with resistances in the range from 100 to 20,000 ohms.

Oscilloscope Camera (27)

FAIRCHILD CAMERA AND INSTRUMENT CORP., 88–06 Van Wyck Blvd., Jamaica 1, N. Y. Equipped for mounting atop standard laboratory oscilloscopes, a 35-mm camera makes still or continuously moving

THE NEW 1947
THORDARSON
Transformer Catalog

ACCLAIMED EVERYWHERE AS THE FINEST YET TO APPEAR, THE NEW 1947 THORDARSON CATALOG IS NOW AVAILABLE.

Describing the complete line of Thordarson Transformers and chokes for replacement and amqteur purposes, this up-to-date catalog also contains circuit diagrams, charts, etc. showing applications for Audio, Power, Modulator, Output and Plate Transformers and Chokes . . . plus complete circuit diagrams for photo-flash power supplies . . . Compiled by the engineering staff of America's oldest transformer manufacturing company, it is a worthy addition to your technical library.

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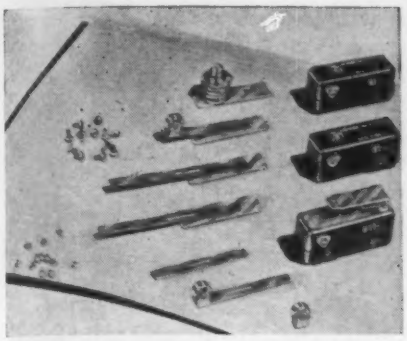
kets, tension devices are two types of Nylon strip designated FM1 and FM3. Melting point of the former is about 505 F. Type FM3 has a lower melting point but is somewhat less hygroscopic.

Precision Switch Kit (30)

UNIMAX SWITCH CORP., 460 W. 34th St., New York 1, N. Y. Using standard components, this design kit comprises a number of precision snap-action switches, and an assortment of Adaptaplates, by means



of which the switches may apply actuating force in various ways. The Adaptaplates include spring-plunger over-travel device for single-hole panel mount, plain leaf, leaf-and-roller, and hinge-arm actuator styles.

Tension Unit and Insulator (31)

DAYTON AIRCRAFT PRODUCTS, INC., 342 Xenia Ave., Dayton 10, Ohio. These antenna tension and insulator units, developed in wartime, are now being made available for com-

mercial and private aviation. They shield the antenna from corona discharge which dangerously interferes with radio communication when aircraft accumulate a static charge in bad weather flying.

Electronic Microammeter (32)

BETA ELECTRONICS CO., 1762 Third Ave., New York 29, N. Y. Model 301

CURRENTLY

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Manufacturers of
VOLTAGE REGULATORS, NOBATRONS & ELECTRONIC APPARATUS

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RUNAWAY VOLTAGES STOPPED AT 1/10 OF 1%

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Input voltage range	95-125
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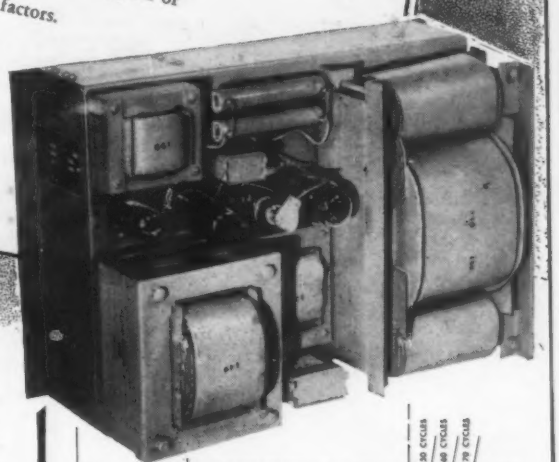
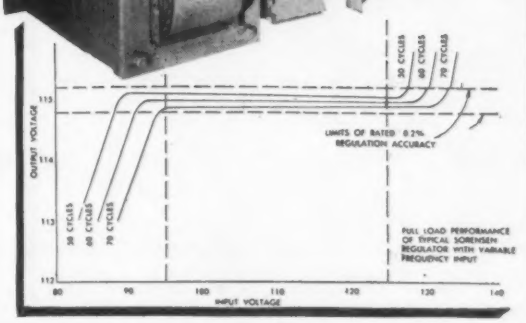
Load range	200-2000 VA
Regulation accuracy	0.2%
Harmonic distortion	2% max.
Recovery time	6 cycles
Input frequency range	55-65 cycles



IT IS "A NATURAL" FOR CONTROLLING VOLTAGES IN LABORATORIES, ASSEMBLY LINE TESTING AND AS A COMPONENT OF YOUR ELECTRICAL UNIT.



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Kester Cored Solders perform better, with a minimum of service difficulties, because Kester solder bonds hold tight under operating ing stresses that would cause ordinary solders to fail.

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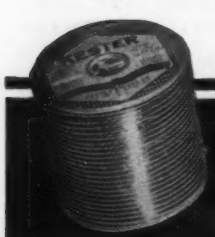

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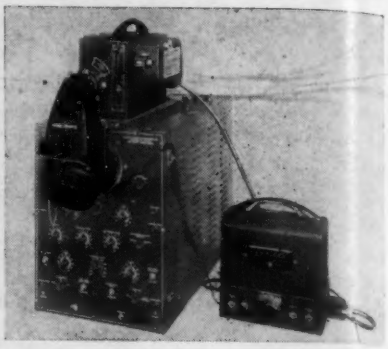


film records of the tube displays. Speed of the film is variable so as to allow recording of successive traces at the instant of their presentation. The film can be driven in conjunction with the sweep or the film itself can be used as the sweep, giving a continuous record.

H-F Antenna (28)

RADIO SPECIALTY MFG. CO., Portland 14, Oregon. This coax-antenna, constructed of aluminum and steel

tubing, will handle inputs up to 250 watts on frequencies between 30 and 200 mc. Maximum weight is 12 pounds.

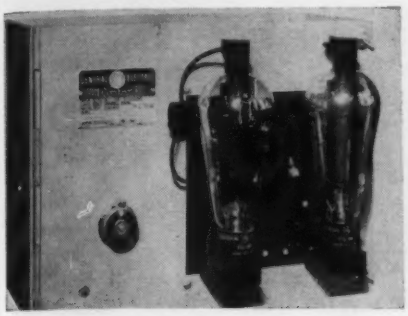
Extruded Nylon Strip (29)

THE POLYMER CORP., Reading, Pa. Now available for blanking in production of washers, spacers, gas-

determines their noise and harmonic content. It also measures frequency and gain characteristics of audio amplifiers. The frequency range as a distortion meter is from 50 to 15,000 cycles; as a voltmeter, from 30 to 30,000 cycles.

Resistance Welding Control (35)

GENERAL ELECTRIC CO., Schenectady, N. Y., announces a new phase-shift heat control accessory for resistance welding machines. It is designed



for use with ignitron contactors or nonsynchronous control combinations not having the heat control feature, when the power supply is 230 or 460 volts.

High-Voltage Midget Capacitors (36)

AEROVOX CORP., New Bedford, Mass. Type PRS midget-can electrolytic capacitors formerly available in voltage ratings up to 450 volts d-c working can now be procured for

working voltages as high as 700 volts. Capacitance values are 8, 10, 12, and 16 microfarads.

Vacuum Monitor (37)

SKANEATELES MFG. CO., INC., 122 Dickerson St., Syracuse 2, N. Y. The type DM Skanascope is an electronic device designed for accurate indication of vacuum pressures in the 1 to 200 micron range. Signals

Strain Recording is INSTANTANEOUS with Brush Oscillographs

The Brush Single-Channel Oscillograph with Amplifier. Oscillographs available in Double and Six-Channel units also.

Instantaneous, permanent, ink-on-paper recordings by Brush Oscillographs make their use almost unlimited. Accurate recordings of strains, pressures and countless electrical phenomena can be made over a frequency range of D.C. to 100 c.p.s. Either A.C. or D.C. signals can be measured. Whenever desired, recordings may be stopped for notations on chart-paper.

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PRECISION

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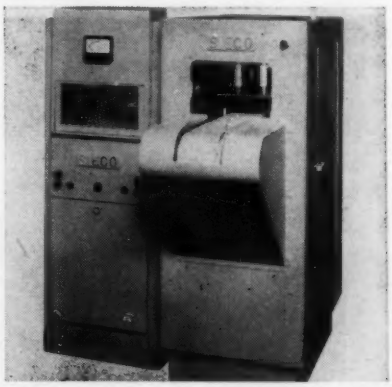
electronic microammeter has five sensitivity ranges from 0.01 microamperes full scale to 100 microamperes full scale with 40 millivolts full-scale input on all ranges. The instrument can also be used as a null-detecting galvanometer with a sensitivity of about 10 millivolts full scale. Write for descriptive literature.

Belt-Type Dielectric Heater (33)

SHERMAN INDUSTRIAL ELECTRONICS CO., INC., 503 Washington Ave., Belleville 9, N. J. The 2-kw belt-type dielectric heater for processing in laboratory or production setups operates from 220-v, 60-cycle



single-phase power. It can operate in either the 13- or 27-mc range, and at full load, power consumption is 3.6 kva. Total weight is 350 pounds.

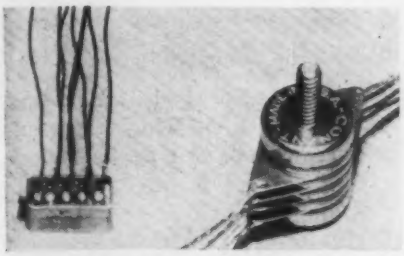
Light-Weight Distortion Meter (34)

BARKER & WILLIAMSON, INC., 237 Fairfield Ave., Upper Darby, Pa. Model 400, weighing 11½ lb, measures low-level audio voltages and

transmitters either as a driver or low-power output, the type GL-2E26 is a five-electrode beam power amplifier with 12.5 watts plate dissipation. Maximum ratings apply up to 125 megacycles.

Experimenters' Rectifier (40)

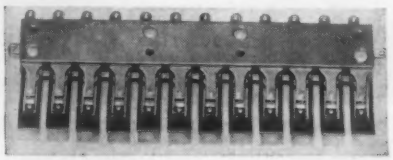
CONANT ELECTRICAL LABORATORIES, 6500 "O" St., Lincoln 5, Neb. A new four-disc instrument rectifier is provided with insulation between each disc and each has its own pair of leads so that all possible combinations or connection can be made.



Type X has 0.5-inch 30-mil discs and type BX-C has 0.165-inch diameter, 5-mil discs.

Gang Switch (41)

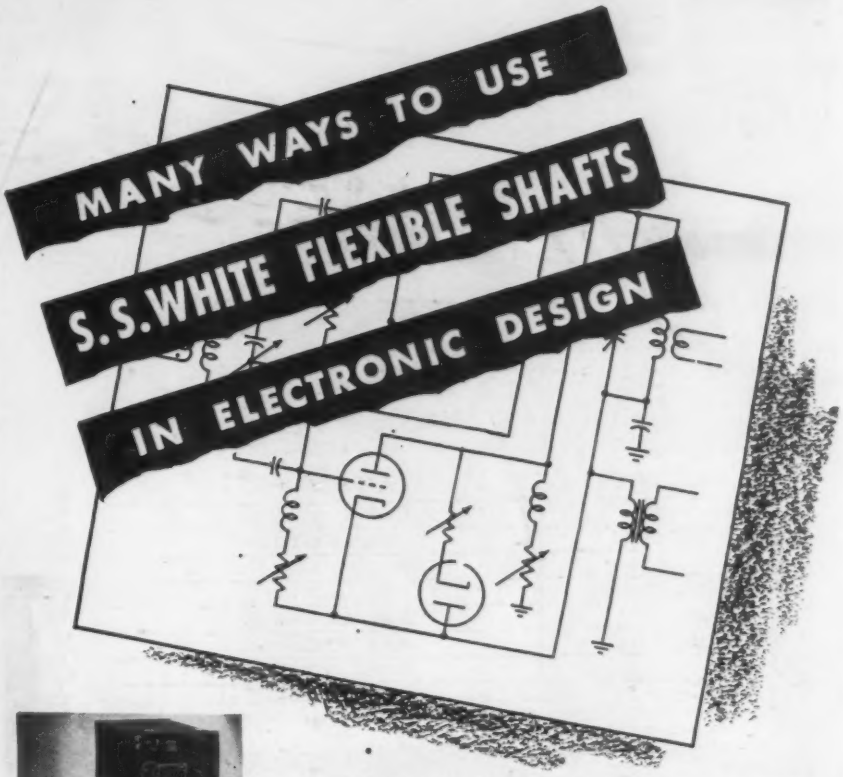
ACRO ELECTRIC CO., 1316 Superior Ave., Cleveland 14, Ohio. A new 12-gang open blade switch illustrated is available with normally open or normally closed combinations for 10-ampere, 125-volt a-c operation.

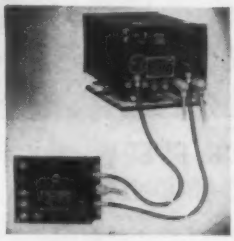


Information on operating force, engineering details, and suggested uses will be furnished by the manufacturer.

High-Current Resistor (42)

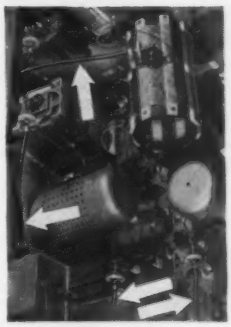
WARD LEONARD ELECTRIC CO., 31 South St., Mount Vernon, N. Y. The Edgeohm high-current resistor consists of a continuous piece of noncorrosive alloy ribbon wound on edge in the form of oval coils. The shape facilitates locating and fastening movable taps. Standard units are rated at 2,200 watts and are available with resistances from 0.32 to 4.35 ohms. Originally designed





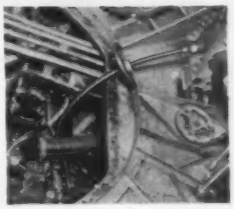
● **USE THEM FOR REMOTE CONTROL**

over long distances and short—as in this aircraft radio receiver. S.S.White remote control type shafts are readily installed and when properly applied, are as easy, smooth and sensitive in operation as a direct connection.



● **USE THEM AS COUPLINGS**

to link variable elements to outside controls—as in this broadcast transmitter. They allow you to locate elements and controls to the best advantage from the standpoints of circuit efficiency, assembly, wiring, servicing and operation.



● **USE THEM FOR POWER DRIVES**

to operate instruments and other mechanisms requiring rotary power—as with this electric tachometer generator. S.S.White shafts of the power drive type meet every need for positive, reliable operation between practically any two points, regardless of curves, obstacles or distance.

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It gives full facts and technical data on flexible shafts and how to apply them. Copy sent free if you write for it on your business letterhead and mention your position.

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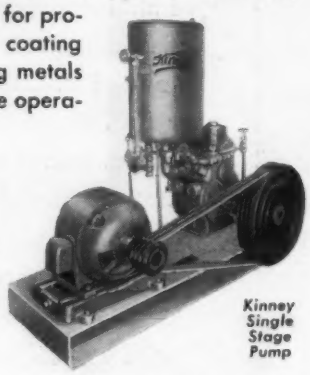

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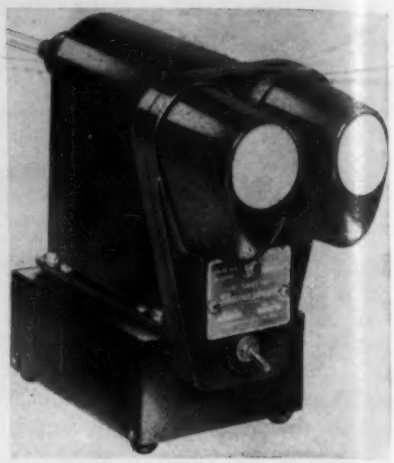
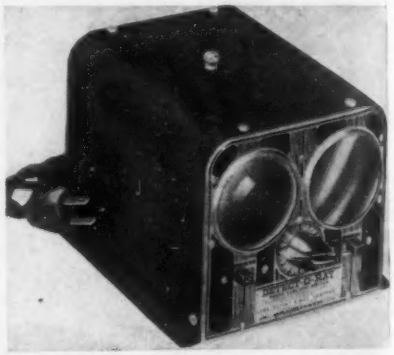
WE ALSO MANUFACTURE LIQUID PUMPS, CLUTCHES AND BITUMINOUS DISTRIBUTORS



• are registered by luminous tube units, connected in series with a pair of gage tubes which, in turn, operate a rated 3-ampere inductive load relay for the actuation of external apparatus.

Photo Switch (38)

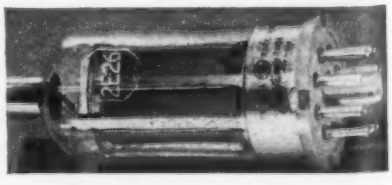
DETECT-O-RAY Co., 2622 N. Halsted St., Chicago 14, Ill. Light source, photoelectric cell, power switch, volume control, visible or invisible beam selector all housed in a single



unit are supplied complete. The reflecting mirror with adjustable bracket is mounted at a distance. The assemblage of equipment can be used for burglar alarm, safety switch, door opener, or similar service.

F-M Amplifier (39)

GENERAL ELECTRIC Co., Schenectady, N. Y. Designed for use in fm



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FUNGICIDAL COATINGS

INSL-X CODE	APPLICATION
27-SA	OVERALL VARNISH
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25X-OB-SA	HOOKUP WIRE
SN-15-OB-SA	WAX SOLUTION
95-OB	OVER-ALL VARNISH
I-1-T	WAX CONCENTRATE
SN-3-T	FABRIC TREATMENT

FUNGICIDAL CODES: A—Phenyl Mercuric Salicylate, T—Phenyl Mercuric Stearate, PA—Pentachlorophenol, SA—Salicylanilide, OB—Phenyl Mercuric Ortho Benzoic Sulphimide

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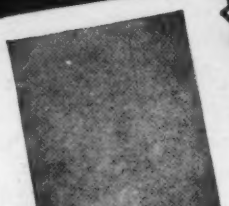
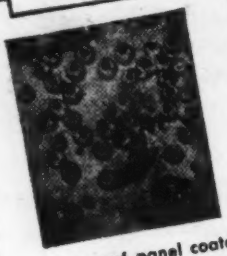


Close up of panel coated with INSL-X "T" Series after 6 months exposure.



Close up of panel coated with standard toxicant after 6 months exposure.

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INSL-X coatings are available in many types, each of which offers the maximum protection for a specific group of requirements—impregnation, surface coating, high dielectric strength, low loss characteristics, etc. All of the coatings are easy to apply, biologically effective, non-toxic to humans and non-corrosive. Chemical and thermal stabilities are excellent and insure long term protection in every application. INSL-X fungicidal coatings meet rigid government specifications.

Write for complete specifications and application data on all INSL-X insulating coatings and compounds—fungicidal and regular; no obligation.

THE INSL-X COMPANY • INC.

MANUFACTURING ENGINEERS OF INSULATING, FUNGICIDAL AND PROTECTIVE ELECTRICAL COATINGS

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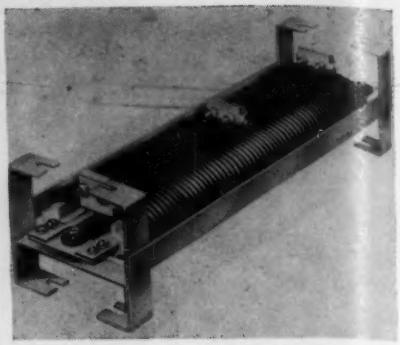


for starting, dynamic braking, and load banks, the new units have similar applications in the electronic field.

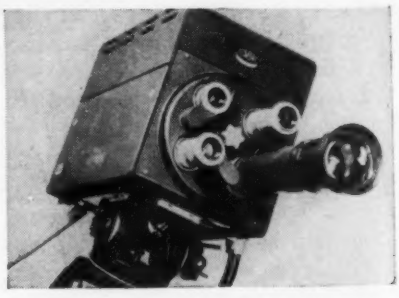
Two-Way Radio (43)

SPERTI INC., Norwood Station, Cincinnati 12, Ohio. The new hand-held radio weighs only 3½ pounds

complete with batteries. It operates in the 144 to 148-mc band up to three miles or farther. Featured in the design is adjustable tuning on both transmitter and receiver.

Image-Orthicon Camera (44)

ALLEN B. DUMONT LABORATORIES, INC., 2 Main Ave., Passaic, N. J. Employing the new supersensitive image-orthicon pickup tube, this



camera features a lens turret that takes up to four lenses of various focal lengths. Turret, diaphragm setting, and focusing are controlled from the rear of the camera. Hinged and removable panels make components and circuits immediately accessible. The electronic viewfinder avoids parallax difficulties.

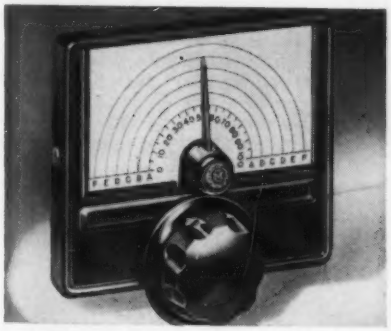
Marine Radio (45)

APPLIED ELECTRONICS Co., San Francisco, Calif. Available in three models with input of 22 watts (four channels) up to 260 watts (ten chan-

nels) the marine radio-telephone equipment illustrated is completely pretuned and prealigned. A feature of the gear is its shallow construction that makes it suitable for bulkhead mounting.

Midget Vernier Dial (46)

JAMES MILLEN MFG. Co., 150 Exchange St., Malden, Mass. Type 10039 multiscale midget dial has a



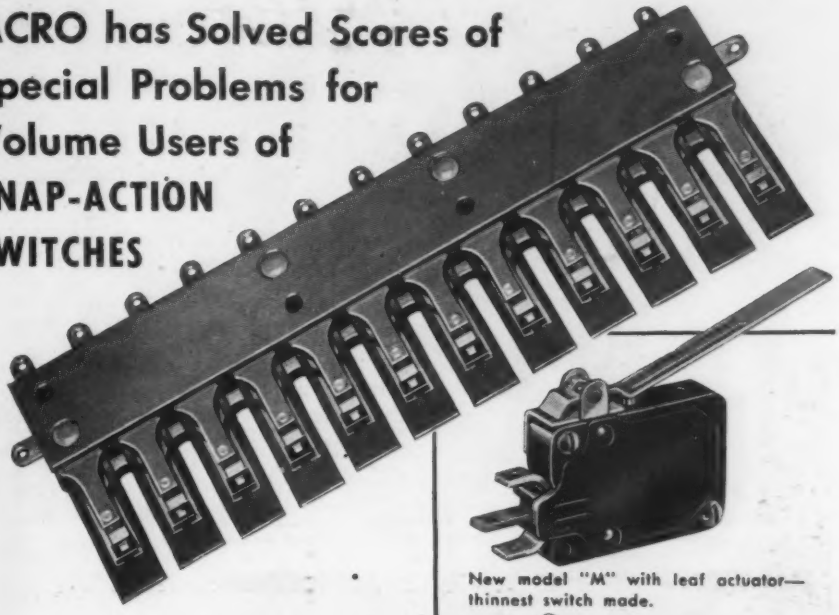
vernier ratio of 8 to 1 and measures 3½ by 4 inches. It is made of black art metal.

Crystal Holder Socket (47)

JAMES MILLEN MFG. CO., INC., 150 Exchange St., Malden 48, Mass. The

What is your SWITCH PROBLEM?

ACRO has Solved Scores of Special Problems for Volume Users of SNAP-ACTION SWITCHES

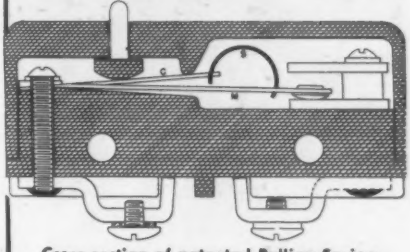


New model "M" with leaf actuator—thinnest switch made.

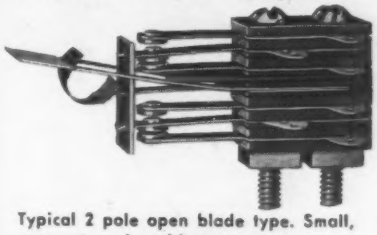
The "Gang Switch" shown above is just one of many examples of special construction by ACRO to simplify one customer's problem of assembling many switching elements into one compact unit. It reduced the number of parts, saved space, and shortened assembly time.

The engineering design of ACRO's patented Rolling Spring Snap-Action construction, permits many remarkable variations from our standard units shown at the right. These variations solve problems of space, multiple circuits, style of mounting, resistance to vibration, and assembly costs. Operating characteristics can be engineered to meet your requirements, with ratings up to 15 Amps. 125 Volts A.C.

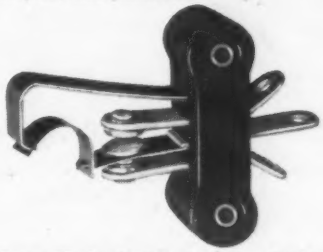
Scores of ACRO's repeat order customers, such as RCA, Wilcox Gay, Packard Mfg. Co., Brush Development Co., Nat'l Slug Rejector Co., St. George Wire Recording Co., Westinghouse, and many others have found that ACRO is pleased to assist in developing special Snap-Action units to fit unusual operating conditions. We welcome **your** problems, too, with full details, for prompt study, without charge.



Cross section of patented Rolling Spring construction in fully enclosed type.



Typical 2 pole open blade type. Small, compact, and positive.



Open Blade Model "M" for limited space and low cost.

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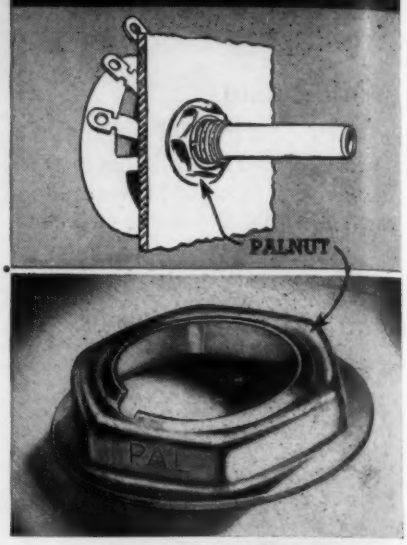

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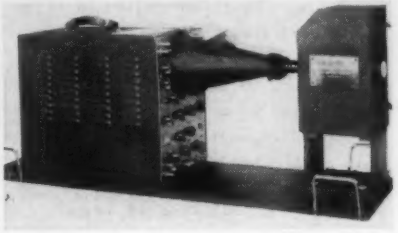
Pickup Arm (48)

BARBER AND HOWARD, East Ave., Westerly, R. I. Model G. 1 pickup arm is designed for use with the GE variable reluctance cartridge.

The arm is fabricated from aluminum and has a stylus pressure of approximately 24 grams with cartridge installed. The head is removable.

Oscilloscope Recorder (49)

ELECTRODYNE CO., 899 Boylston St., Boston 15, Mass. Custom-built recorders for ionosphere or telemetering research can be fabricated



on short order following basic specifications available from the manufacturer. Machines can be furnished for use with continuously moving tape or film.

Dual C-R Tube (50)

ELECTRONIC TUBE CORP., 1200 E. Mermaid Ave., Philadelphia 18, Pa. Type 5Z2P-S1 dual-gun electrostatic focus and deflection c-r tube has an additional pair of deflecting plates provided for each electron gun. The additional pair of plates is particularly useful in deflecting a beam along the one axis by application of two isolated inputs instead of one composite input. Sug-

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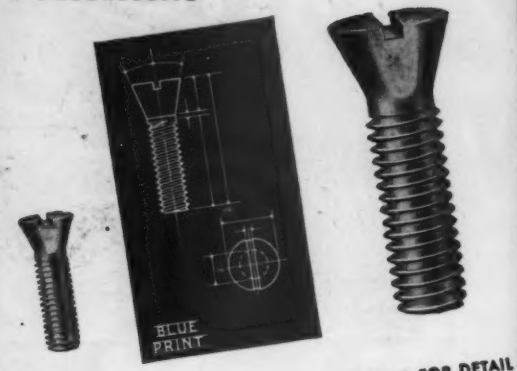

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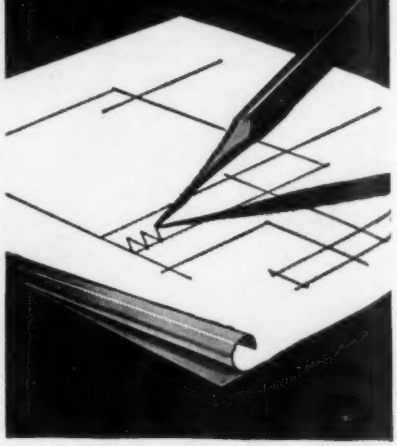

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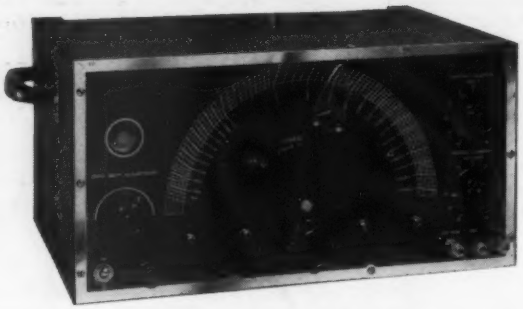
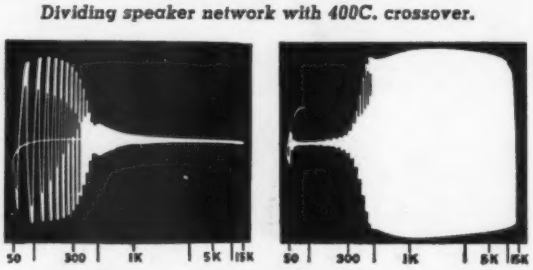


Dividing speaker network with 400C. crossover.



The CLOUGH BRENGLE CO.

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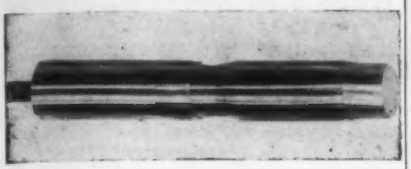
gested uses, which may not be immediately apparent, and further technical information are available.

Microphone Multipliers (51)

MASSA LABORATORIES, INC., 3868 Carnegie Ave., Cleveland 15, Ohio. Multipliers for extending the dynamic range of sound-pressure measurement equipment are inserted between the M-101 microphone and the M-109 socket, as illustrated. Two units are available



both extending range from 20,000 dynes per square centimeter up to 200,000 dynes per square centimeter, but for different frequency ranges.

Thermistor Bridge (52)

SYLVANIA ELECTRIC PRODUCTS INC., 500 Fifth Ave., New York 18, N. Y. Two new thermistor bridges, types TBN-7SE and TBN-6SE provide r-f

power measurements up to two milliwatts at frequencies in the shorter microwave region. Good accuracy is provided up to this power level. Further information is available.

Quick-Heating Thyratron (53)

NATIONAL ELECTRONICS, INC., Batavia Ave., Geneva, Ill. The NL-714

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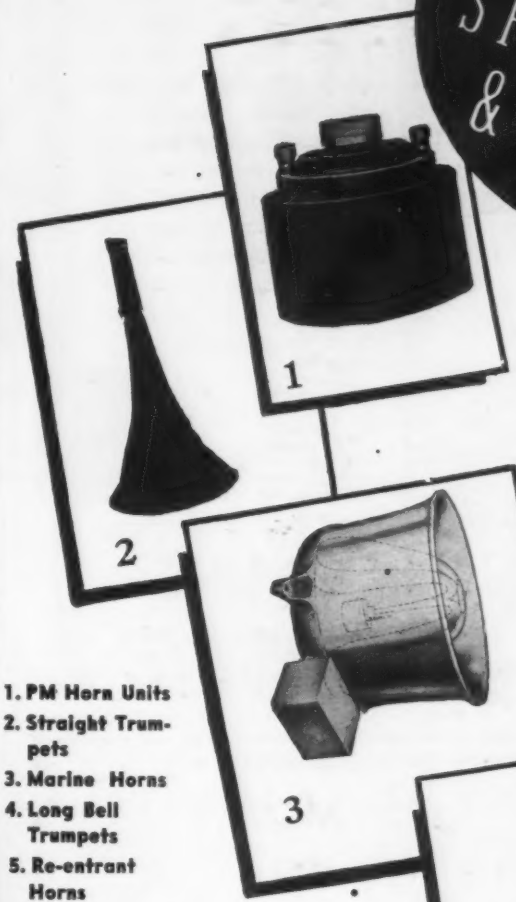

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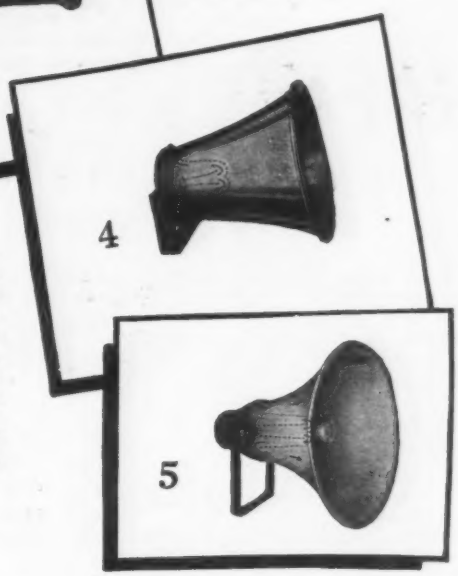

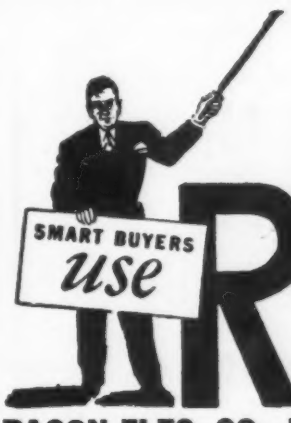

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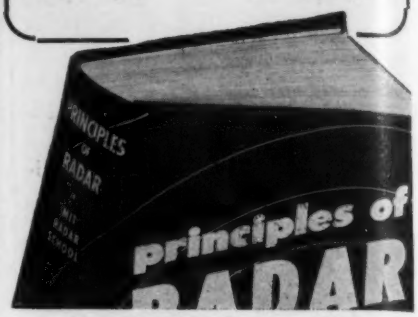

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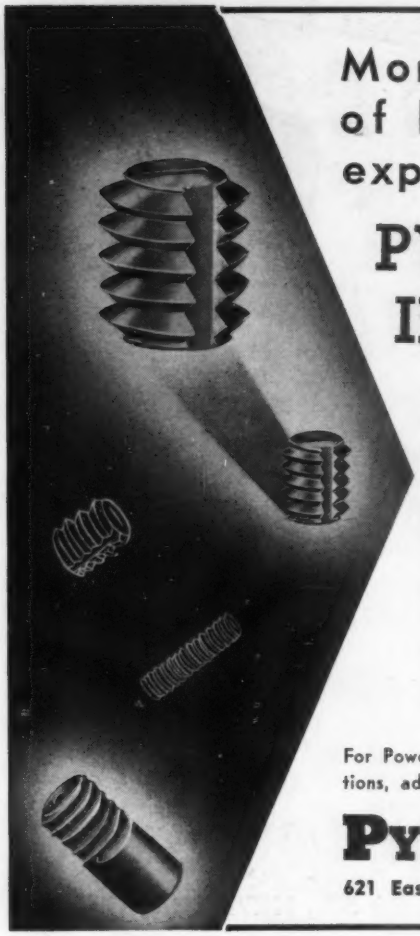

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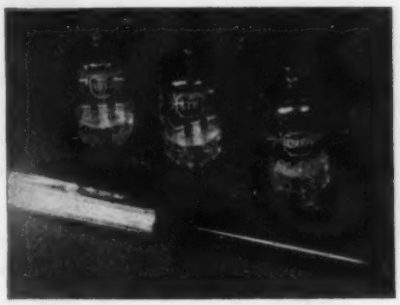
Television Coil Kit (54)

RAY-LECTRON CO., Belmar, N. J. A television coil kit and instruction book make it possible for the amateur or experimenter to build his own television receiver for about $125. Kit and manual are $23.50.

Miniature Receiving Tubes (55)

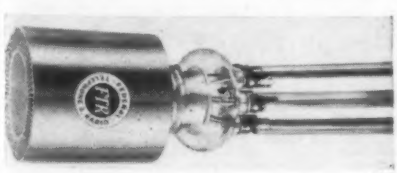
GENERAL ELECTRIC CO., Syracuse, N. Y. Three new 9-pin miniature tubes recently developed are the types 6T8, 19T8, and 12AT7. The latter is a twin-triode for use as a grounded-grid r-f amplifier or converter at frequencies below 300 mc.



Both the triple-diode triodes contain three high-perveance diodes and a high-mu triode in the same envelope. They are designed as combined a-m and f-m detectors and audio-frequency amplifiers.

Industrial Heating Tube (56)

FEDERAL TELEPHONE AND RADIO CORP., Clifton, N. J. Type 7C25, a 2,500-watt oscillating tube, is designed for use in dielectric heating. Two tubes in a coupled circuit will give a power output of 4½ to 5 kw at frequencies up to 50 mc. Com-



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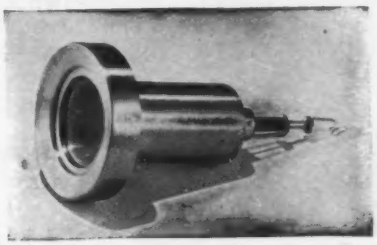

The VX-A series of subminiature electrometer tubes now incorporate a new low microphonic feature to add to the already outstanding characteristics of these tubes such as filament current of 10 ma. and grid resistance of 1015 ohms minimum. Designed for instrumentation where performance is exacting and especially in many types of radiation measuring instruments their need is vital. Available also as diodes, triodes and tetrodes.

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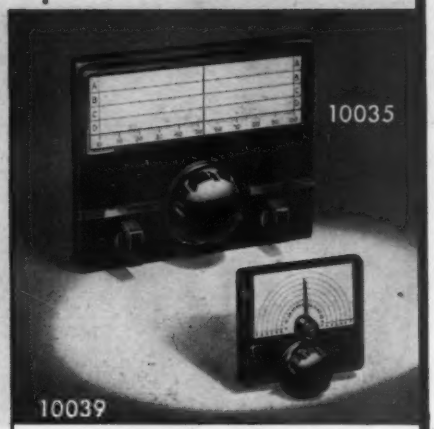

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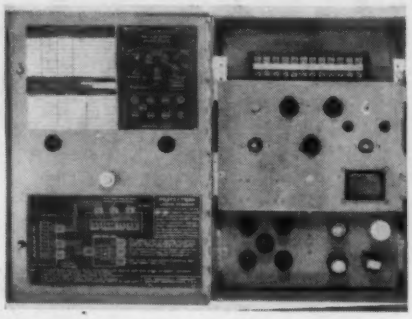
plete technical data, with dimensional diagram and graphs, are given in a 4-page folder.

Machine Protector (57)

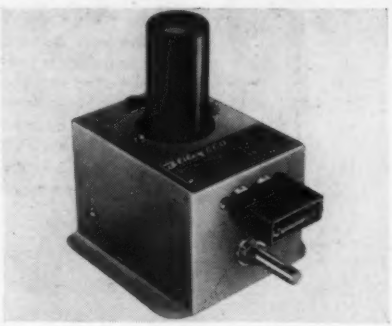
THE BRINNELL CO., Granby, Conn., manufactures the Protectron, an electronic device for use in conjunction with an electric motor-



driven machine to trip at any preset mechanical load increase above normal. It is available for 220 and 440 volt 60-cycle motors in two models; for operating current of 1 to 5 amperes and 5 to 10 amperes.

VHF Xtal (58)

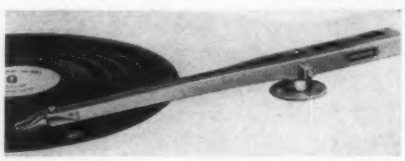
BLILEY ELECTRIC CO., Erie, Pa. A crystal controlled oscillator unit CCO model 2A is a packaged unit for crystal control of 2, 6, 10, and



11 meter transmitters. A type 6AG7 tube and AX2 or AX3 crystals are used. Send for Bulletin 34.

Studio Pickup (59)

AUDAK CO., 500 Fifth Ave., New York, N. Y. Model Studio-81 has sufficient gain for most conventional



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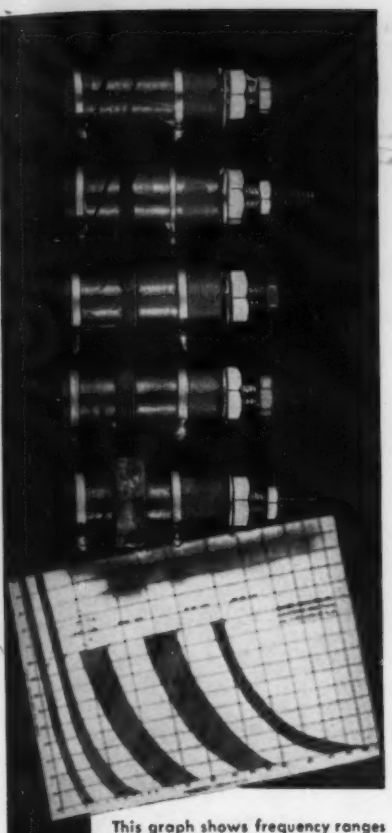

This graph shows frequency ranges covered by each unit. Write us for your full-size copy.

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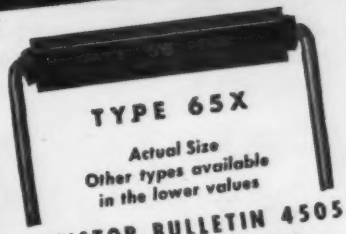

RESISTOR BULLETIN 4505 GIVES FULL DETAILS...

It shows illustrations of the different types of S. S. White Molded Resistors and gives details about construction, dimensions, etc. A copy, with Price List will be mailed on request. Write for it—today.

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- **Strong and durable**
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1000 ohms to 10 megohms
• NOISE TESTED •

At slight additional cost, resistors in the Standard Range are supplied with each resistor noise tested to the following standard: "For the complete audio frequency range, resistor shall have less noise than corresponds to a change of resistance of 1 part in 1,000,000."

HIGH VALUES
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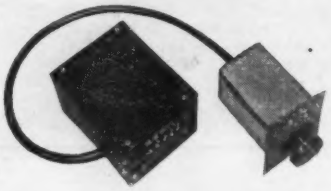
GRAY Model 601 Equalizer



4-position, standard broadcast type, 250-ohm impedance; designed to complement the GE Variable Reluctance cartridge mounted in a Gray Transcription Arm. Net $42.50

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High gain, low noise level pre-amplifier for use where high quality amplification is desired.

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Combining high and low frequency units in one horn. Range: 50 to 50,000 cycles.

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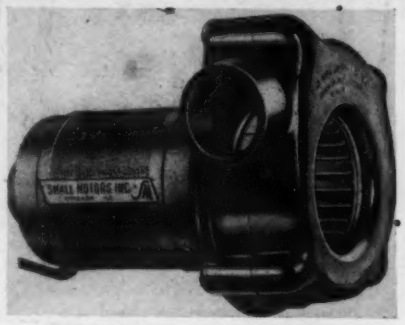
amplifiers, small dynamic mass and linear response to better than 10 kc. Point pressure is 14 grams.

Ventilating Device (60)

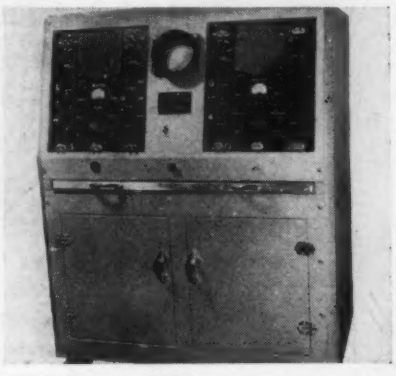
SMALL MOTORS, INC., 2076 Elston Ave., Chicago, Ill., has developed the B-2 blower for ventilating and



cooling electronic tubes, projectors and other units. It operates on 110 volts, a-c and d-c.

Dual Channel Oscilloscope (61)

ELECTRONIC TUBE CORP., 1200 E. Mermaid Ave., Philadelphia 18, Pa. Model E-2G15 dual channel oscilloscope comprises two separate channels operating into a single dual-gun



cathode ray tube. Provisions are made for various connections to increase the versatility of the instrument. Further details, including price, are available in mimeographed form from the manufacturer.

Twin Diode (62)

HYTRON RADIO & ELECTRONICS CORP., Salem, Mass. Type 12AL5 twin diode is intended for use as a detector in circuits utilizing wide-band amplifiers. It can be used as

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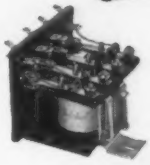

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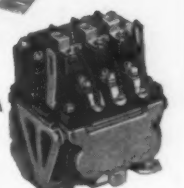

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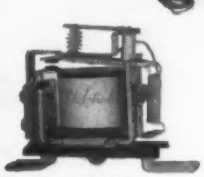

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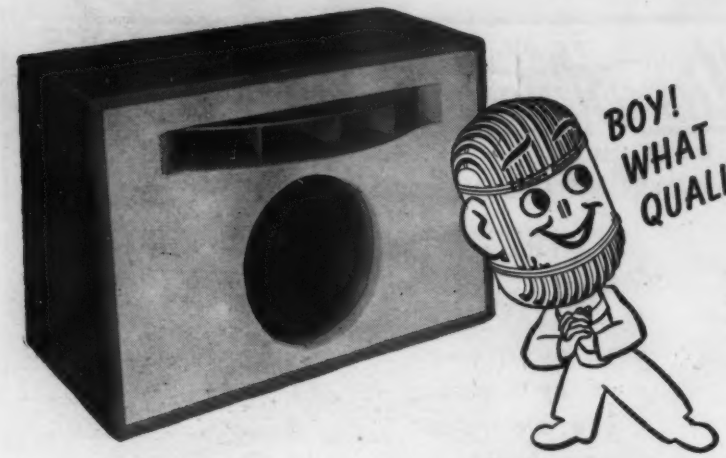

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The Brook High Quality Triode Amplifier surpasses every requirement of the most exacting application. Its wide frequency and dynamic ranges—freedom of distortion—and stability of characteristics from zero to maximum output of 30 watts—have never before been achieved except under controlled laboratory conditions.

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★Flat within 0.2 db from 20 to 20,000 cycles at nominal output. Within 1.5 db at full power output of 30 watts. Down 1 db at 4 cycles at 1 watt.

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★Five Stages—Last three push-pull.

★Noise level 70 db below full output.

★Automatic Bias Control.

★Calibrated Bass and Treble Compensation. Tapped Multi-Stage R-C network.

★All transformers completely free from saturation or leakage reactance effects from 25 to 20,000 cycles.

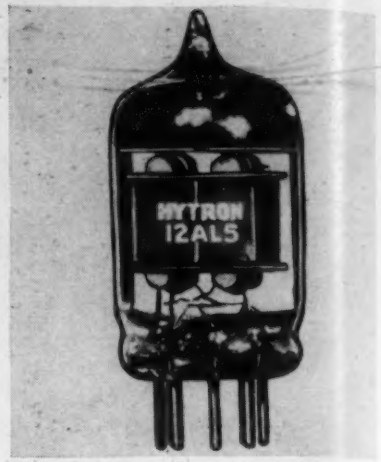
★Gain—55 to 120 db in various models.

★Output—1.5 to 30 ohms and 500 ohms.

★Power available for External Tuner—250 volts at 90 mils and 6.6 volts at 5 amps.

The BROOK High Quality Audio Amplifier
Designed by Lincoln Walsh

BROOK ELECTRONICS, Inc., 34 DeHart Place, Elizabeth 2, N. J.



a discriminator, ratio or diode detector, avc. diode, clipper, or low-power rectifier. Each set of elements can be used independently of the other and each has a resonant frequency of about 700 megacycles.

Equalizer

A. F. SMUCKLER & Co., 338 East 23rd St., New York 10, N. Y. The Afsco equalizer type 200X-1B was described in item 2, New Products department, of the October issue of ELECTRONICS. Both the trade and company names were misspelled.

Literature

(63)

Monochromators. Farrand Optical Co., Inc., Bronx Blvd. & E. 238th St., New York 66, N. Y. Bulletin 801 covers the design, operation, and performance of a monochromator for research in the ultraviolet spectral region.

(64)

Special Oscilloscope. Allen B. DuMont Laboratories, Inc., 1000 Main Ave., Clifton, N. J. Type 256-D cathode-ray oscilloscope is an outgrowth of the MIT Radiation Laboratory type 256-B A/R range scope. The new commercial equipment has delay dial and markers calibrated in terms of microseconds. Characteristics available in printed form.

(65)

Antenna Rotator. Gordon Specialties Co., 542 So. Dearborn St., Chicago 5, Ill., has an attractive two-color folder showing a line of equipment suitable for construction or erection of rotary antenna

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Reduce Production Costs

Bradley Luxtron* photocells improve control over manufacturing operations, reducing your costs. They meet the most exacting requirements. Advanced manufacturing techniques make light-actuated Bradley cells the choice all over the world.

Luxtron photocells convert light directly into electrical energy. No external source of voltage is required. Besides the housed model shown with its plug-in contacts, Bradley also offers tube socket, nut-and-bolt types and pigtail contact mountings. In addition, Luxtron unmounted cells are available in many different sizes and shapes.

*T. M. REG. U. S. PAT. OFF.

Illustrated literature, available on request, shows more models of Bradley photocells, plus a line of copper oxide and selenium rectifiers. Write for "The Bradley Line."

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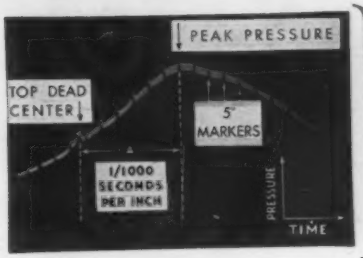

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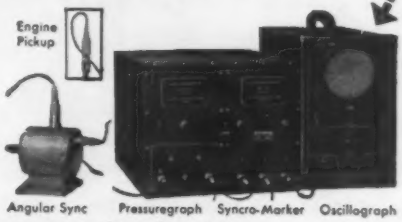

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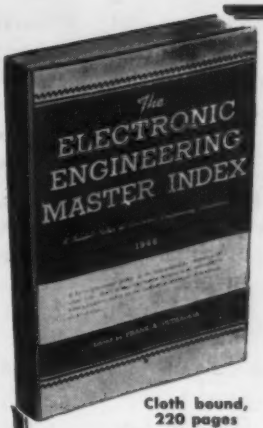

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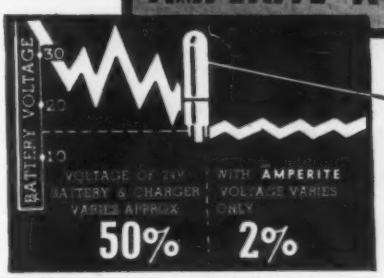

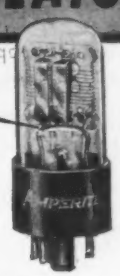

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beams for transmitting or receiving on the higher frequencies.

(66)

Picture Tube. Sylvania Electric Products Inc., Emporium, Pa. Specifications sheets on the 7-inch picture tubes 7GP1 and 7GP4 have recently been issued.

(67)

Film Recorders. The Electrodyne Co., 899 Boylston St., Boston 15, Mass. A three-page mimeographed publication lists types of moving film or paper recorders for oscilloscopes.

(68)

Extrusion Devices. Industrial Ovens, Inc., 13825 Triskett Road, Cleveland, Ohio. Those interested in the fabrication of thermoplastic insulated wire, cable, and tubings will find a recent 12-page illustrated brochure of use. It describes continuous takeup devices.

(69)

Amplifiers. R. W. Neill Co., 1811 Carroll Ave., Chicago 12, Ill. Model 710-A way-station amplifier designed for amplification of low level signals or voice from telephone transmission lines to loudspeaker volume.

(70)

Marine Radar. Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30, Pa., announces publication of a new booklet (B-3845-A) dealing with marine radar. Installation views of radar equipment and actual radar scope photographs taken at strategic points are contained therein.

(71)

Mixer Information. The Daven Co., 191 Central Ave., Newark, N. J. A new folder contains a table showing impedance versus decibel loss with values calculated for impedance mismatch, minimum T loss, and bridging-pad loss. Data on mixer circuits are also shown.

(72)

Small Tubing. Superior Tube Co., 2112 Germantown Ave., Norristown, Pa. Bulletin 31 lists information on seamless as well as welded and drawn small tubing in various

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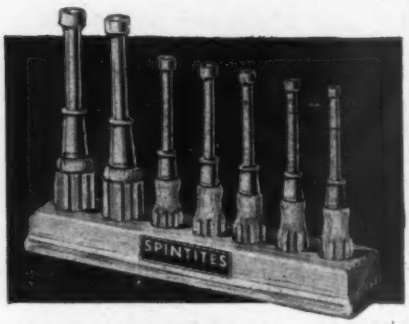
Ranging in size from 3/16" to 5/8", Spintites are available to fit square, hex, or knurled nuts.

When time is of the essence, there's no substitute for Spintites.



T-73 Set, has 7 sizes of hex heads. Shock-proof handles, and cold forged sockets assure safety and strength.

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STEVENS • WALDEN
INCORPORATED
Worcester • Massachusetts

Instruments... for nuclear research

MODEL 161 SCALER

Built-in high voltage supply, rapid circuit reaction, reliable operation even with wide variations of line voltage, facilities for timing clock and external register, and simplicity of operation make this scaler suitable for use in all types of research or routine counting work. Predetermined time and count features also available.

MODEL 2610 PORTABLE COUNT RATE METER

This radioactivity survey meter is completely self-contained and easily portable. (Weight only 9½ lbs.) Complete with meter and earphones.

MODEL 3340 POCKET METER

Lightweight, pocket-size meter for recording the amount of radiation to which its wearer has been subjected. Durable and not easily subject to damage. Extremely insensitive to shock. Constructed of sturdy, attractive plastic material.

ACCESSORIES

A complete line of tubes, quench circuits, counters, shields, and other accessories is available. Special products can also be manufactured to meet your needs. Write Dept. D for catalog and other information.

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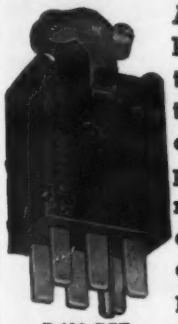
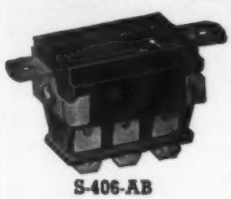
JONES 400 SERIES PLUGS and SOCKETS



P-406-CCT

A medium size Plug and Socket that fulfills practically every requirement in the public address, radio and kindred fields. Socket contacts are of phosphor bronze, cadmium plated.



S-406-AB

Plug contacts are of hard brass, silver plated. Insulation is of molded Bakelite. All Plugs and Sockets are Polarized. Made in 2, 4, 6, 8, 10 and 12 contacts. Caps are of steel with baked black crackle enamel. A quality item at popular prices.

Send today for catalog No. 14 listing complete line of Jones Electrical Connecting Devices—Plugs, Sockets and Terminal Strips.

HOWARD B. JONES DIVISION
CINCH MFG. CORP.
2460 W GEORGE ST. CHICAGO 18

G-E Variable Reluctance Pickup

CHECK these characteristics of the G-E Variable Reluctance Pickup against your present reproducer head. Make your own exacting tests. Prove to yourself that this pickup will improve the reproduction quality given by your own phonographs.

The G-E Variable Reluctance Pickup has:

- **No resonant peaks.**
- **Wide frequency response—essentially flat from 30 to 8000 cycles.**
- **High compliance of the stylus—hence more faithful reproduction and exceptionally low record wear.**
- **Self protecting genuine sapphire stylus.**
- **Virtual freedom from "needle talk".**
- **Practical insensitivity to vertical vibration—the source of surface noise.**
- **Stability under humidity, heat and cold.**

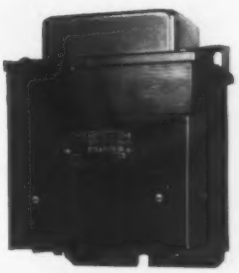
We are equipped to make prompt delivery to meet your production schedules. For complete information on this finer pick-up write *General Electric Company, Electronics Park, Syracuse, N. Y.*

GENERAL ELECTRIC

168-F4

NEW . . . the MULTI-PURPOSE *ELECTRAN* STEP-DOWN TRANSFORMER

ONE TRANSFORMER OR *THREE* —
OPERATES FROM 230 and/or 460 V. LINES



1. Permits use of combination power and light circuits — one entrance service — one meter — one central conduit to run.

2. Allows maximum power distribution on minimum sizes of wiring — smaller conduit runs result in installation cost savings.

3. Old installations can be made to handle greater loads by increasing voltages at the distribution panel and installing step-down transformers at machines or other power take-off points.

4. Permits 115/230 volt single phase lighting circuits to be operated direct from 3 phase 460 volt mains.

5. Results in savings when power is bought at higher voltages — less copper line loss is experienced.

WRITE FOR BULLETIN

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metals. Nickel cathodes and similar types useful to the electronic engineer are described.

(73)
Variable Speed. Louis Allis Co., Milwaukee 7, Wis. Bulletin 611C describes the Adjusto-Spede that is designated an alternating current adjustable speed drive using electronic principles.

(74)
Ceramics. General Ceramics and Steatite Corp., Keasbey, N. J. Engineers will be glad to have a copy of the 32-page booklet on the subject of dielectric and other ceramics, including a bibliography on the subject.

(75)
H-V Resistors. International Resistance Co., 401 N. Broad St., Philadelphia 8, Pa. A four-page technical data bulletin gives complete specifications and characteristics of type MV high-voltage resistors in the power range from 2 to 90 watts. Ask for bulletin G-1.

(76)
Plastic Insulation. Bakelite Corp., 30 E. 42nd St., New York 17, N. Y. Booklet No. 16 consists of eight pages of technical data on Vinylite plastic wire and cable insulating compounds. Included are tables giving their physical and electrical properties.

(77)
Recorder-Controller. Wheelco Instruments Co., 847 W. Harrison St. Chicago 7, Ill., is releasing an 8-page two-color bulletin C2 that describes the Capacilog electronic recorder and controller for industrial processes.

(78)
Coil Winder. Allied Control Co., 2 East End Ave., New York, N. Y. Information is available on a new coil winder that can be operated at 6,500 rpm using fine wire.

(79)
Radio Wire. Cornish Wire Co., Inc., 15 Park Row, New York, N. Y., is distributing a four-page catalog of electrical, radio and industrial wires, cables, and spe-

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ONE-PIECE STRENGTH
PERMANENT TIGHTNESS
FAST PRODUCTION
SURPRISING LOW COST
NO MAINTENANCE

Whether you have only a few electrical connections to make, or thousands—there's no simpler, faster, more economical way to make them than brazing with SIL-FOS. That goes for terminals, lugs, leads, coil windings, bus bars or any other copper connections. Actually, connections made with this fast-acting, low-temperature silver brazing alloy, *equal the unjoined metal* in all properties you need in electrical connections.

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BULLETIN 12-A

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Electronamic Test Master
SERIES 10-20
Combination
Tube PERFORMANCE Tester,
Battery Tester and
34 range AC-DC Circuit Tester

* *Reg. Pend. U. S. Patent Office*

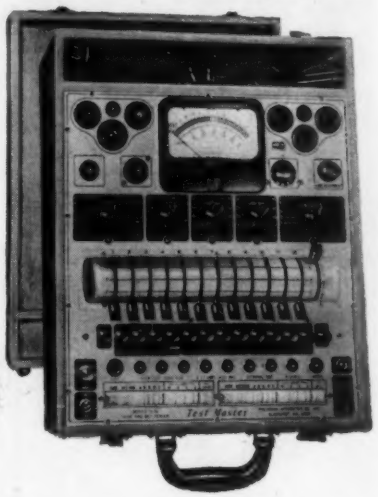
* A tube tested for just one characteristic does not necessarily reveal overall performance capabilities. In the Precision Electronamic Tube Tester, the tube is electro-dynamically swept over a complete Path of Operation, on a sinusoidal time base which is automatically integrated by the meter in direct terms of Replace-Weak-Good.
Affords highest practical order of obsolescence insurance thru use of the Precision 12 station Master Lever Element Selector System.

THE SERIES 10-20 TEST MASTER

is particularly engineered for general-purpose industrial and electronic maintenance, service and installation. Tests all modern standard receiving and low power transmitting tubes; including facilities up to twelve individual element prongs; dual-capped H.F. amplifiers, 5 & 7 pin acorn types, Noval 9 pin tubes, etc.

CIRCUIT TESTING FEATURES

34 self-contained ranges, to 3000 volts, 10 megohms, 12 amperes, + 64DB. • 400 microampere, 4½" meter • All standard functions at only two tip jacks • Push-button range selection.



MODEL 10-20-P in portable hardwood case (illustrated) $109.10
Also available in counter and panel mount models.

All models include
test leads and ohmmeter batteries.

"Precision" Master Electronamic Test Instruments now on display at all leading radio equipment distributors. Write for the Precision 1948 catalog fully describing the Electronamic tube performance testing circuit.

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This versatile metal forming machine was developed for use in model shops, experimental laboratories and production departments where it often replaces dies for all types of precision forming operations. Di-Acro Brakes will form a great variety of materials including bronze, stainless steel, aluminum and bi-metals.

WRITE FOR CATALOG. New edition of 40-page Di-Acro Catalog contains detailed information on all Di-Acro Brakes, Shears, and Benders and illustrates how these precision machines can be used individually or cooperatively for "DIE-LESS DUPLICATING".

◀ DI-ACRO is Pronounced "Die-Ack-Ro"

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Inside Perimeters from .592" to 19"

With specialized experience and automatic equipment, PARAMOUNT produces a wide range of spiral wound paper tubes to meet every need . . . from ½" to 30" long, from .592" to 19" inside perimeter, including many odd sizes of square and rectangular tubes. Used by leading manufacturers. *Hi-Dielectric, Hi-Strength.* Kraft, Fish Paper, Red Rope, or any combination, wound on automatic machines. Tolerances plus or minus .002". Made to your specifications or engineered for YOU.

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cialties such as antenna accessories.

(80)

Sky-Broadcasting. University Loudspeakers, Inc., 225 Varick St., New York, N. Y. Currently off the press is a four-page bulletin compiled by the technical staff on the use of loudspeakers for airplane sound-broadcasting service. Power requirements (100 watts or more), methods of installation, and approximate weights are presented as an aid to those contemplating aircraft use. There is no charge for the bulletin.

(81)

Handie-Talkie. Motorola, Inc., 4545 W. Augusta Blvd., Chicago 51, Ill. The crystal-controlled f-m handie-talkie weighs only 8½ pounds. Its receiver has a power output of 2.5 milliwatts, and the transmitter, 0.6 watts. The unit is fully described in an illustrated folder. Also available is a small 24-page booklet on two-way communications equipment.

(82)

Photoelectric Cells. Selenium Corp. of America, 2160 E. Imperial Highway, El Segundo, Calif., has a 12-page brochure on selfgenerating photoelectric cells. Characteristics, applications and design factors are included, along with appropriate diagrams.

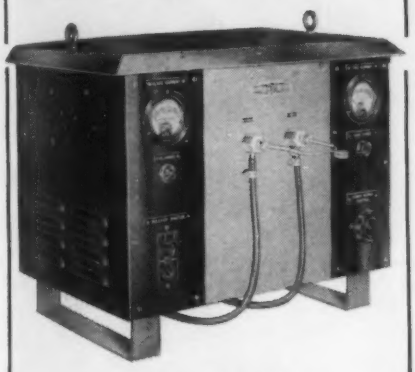
(83)

Relays. Phillips Control Corp., 612 N. Michigan Ave., Chicago 11, Ill. Catalog No. 7 describes and illustrates a variety of a-c and d-c relays designed for electronic and industrial control, signal and traffic control, radio and communication. Coil characteristics, contact assemblies, operating and release times and dimensional drawings of each are given.

(84)

Ultrasonic Gage. Sperry Products, Inc., 15th St. and Willow Ave., Hoboken, N. J. The Reflectogage is an ultrasonic device for thickness measurement and the inspection of bonds. Technical data sheet 3700 explains the principle of operation and methods of use.

NOW— A QUALITY 2-KW INDUCTION HEATING UNIT



For Only $650.

Never before a value like this new 2-KW bench model "Bombarder" or high frequency induction heater . . . for saving time and money in surface hardening, brazing, soldering, annealing and many other heat treating operations.

Simple . . . Easy to Operate . . . Economical Standardization of Unit Makes This New Low Price Possible

This compact induction heater saves space, yet performs with high efficiency. Operates from 110-volt line. Complete with foot switch and one heating coil made to customer's requirements. Send samples of work wanted. We will advise time cycle required for your particular job. Cost, complete, only $650. Immediate delivery from stock.

Scientific Electric Electronic Heaters are made in the following range of Power: 1-3-5-7½-10-12½-15-18-25-40-60-80-100-250-KW.—and range of frequency up to 300 Megs. depending on power required.

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- *DEPENDABLE*
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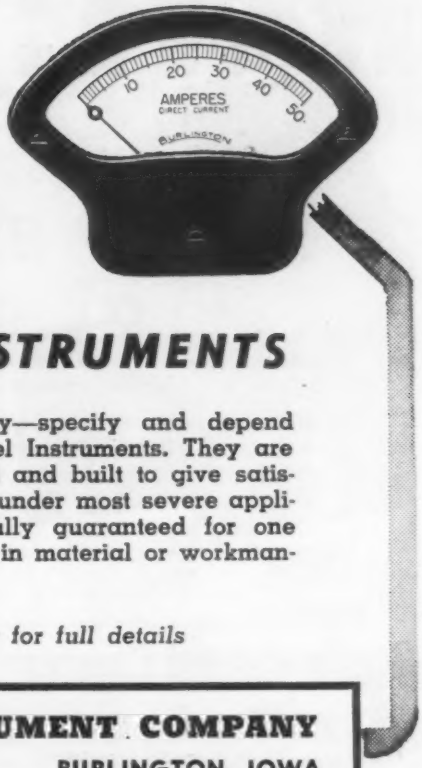

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For utmost reliability—specify and depend upon Burlington Panel Instruments. They are designed, engineered and built to give satisfactory service even under most severe applications—and. are fully guaranteed for one year against defects in material or workmanship.

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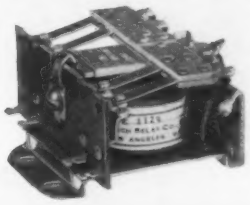

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You will find Leach Relays rendering service around the electrical world: in Industry, Electronics, Communications, Aviation, Transportation and Power.

During the past thirty years, Leach has faithfully maintained its policy of building quality equipment; and today, you'll find Leach delivers *quality* in *quantity*. The name LEACH stands for "better relays" and assures you of "better controls."

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NEW!

35mm
FAIRCHILD
Oscillo-Record Camera

Once again, Fairchild has met a great need of the electronic laboratory—with the first general purpose, easy to use camera ever designed specifically for recording *both* still and continuous cathode ray oscillograph images.

Fairchild's complete assembly consists of a 35mm roll film Camera, Electronic Film Speed Control Unit, Periscope Cone, Mount, Cables and Data Card Unit. *Film speed* can be varied from 1 inch per minute to 3,600 inches per minute. *Exposure capacity* ranges from double frame single exposures to continuous exposures up to 100 feet internal and 400 to 1,000 feet with external magazines. *Recording time* with 100 foot reels is 20 seconds to 20 hours; with 1,000 foot reels it is 3⅓ minutes to 8⅓ days—with the speed recorded along the edge of the film. *Hand written data* can be recorded at the beginning and end of each run.

Fairchild's new OSCILLO-RECORD CAMERA is so simple to set up and operate that anyone in the laboratory can record perfect oscillograph images. Want more details? Address: 88-06 Van Wyck Boulevard, Jamaica 1, New York.

Fairchild CAMERA
AND INSTRUMENT CORPORATION

November 17, 18 and 19, 1947, has been announced as follows by Virgil M. Graham, chairman:

9:30 A.M. Monday Nov. 17—Chairman—A. E. Newlon:

V-H-F Direction Finder for Airport Use, by A. G. Richardson of Federal Telecommunication Laboratories

R-F Inductance Meter with Direct Reading Linear Scale, by Harold A. Wheeler of Wheeler Laboratories Inc.

Design and Layout of Radio Receivers and the Maintenance Man, by A. C. W. Saunders of Saunders Radio & Electronics School

12:30 P.M.—Group Luncheon

2:00 P.M.—Chairman—B. S. Ellefson:

Use of Miniature Tubes in AC/DC Receivers for AM and FM, by R. F. Dunn of RCA

Two Signal Performance of Some F-M Receiver Systems, by B. D. Loughlin and D. E. Foster of Hazeltine Electronics Corp.

6:30 P.M.—Group Dinner

8:15 P.M.—Chairman—George R. Town:

Engineering Responsibilities in Today's Economy, by E. F. Carter of Sylvania

9:15 P.M.—Stag Party, Courtesy of American Lava Corp.

9:30 A.M. Tuesday Nov. 18—Chairman—L. C. F. Horle:

Avenues of Improvement in Present Day Television, by Donald G. Fink of ELECTRONICS

Standardization of Transient Response of Television Transmitters and Receivers, by R. D. Kell and G. L. Fredendall of RCA Laboratories

Psychoacoustic Factors in Radio Receiver Loudspeaker Selection, by Hugh S. Knowles of Jensen Manufacturing Co.

12:30 P.M.—Group Luncheon

2:00 P.M.—Chairman—Clinton B. DeSoto:

Spectral Energy Distribution of Cathode Ray Phosphors, by R. M. Bowie and A. E. Martin of Sylvania

Quality Control in Receiving Tube Manufacture, by J. A. Davies of G-E

6:15 P.M.—Cocktail Party Courtesy of Stackpole Carbon Co.

7:00 P.M.—Fall Meeting Dinner (Stag); Toastmaster Ralph A. Hackbusch:

The British Radio Industry Today, by Fred S. Barton

9:30 A.M. Wednesday Nov. 19—Chairman—B. E. Shackelford:

Metallized Film Coaxial Attenuators, by John W. E. Griemsmann of Polytechnic Institute of Brooklyn

I-F Selectivity Considerations in F-M Receivers, by R. B. Dome of G-E

A New Television Projection System, by William E. Bradley of Philco

12:30 P.M.—Group Luncheon

2:00 P.M.—Chairman—R. M. Wise:

The Organization of the Work of the I.R.E. Technical Committees, by L. G. Cumming of I.R.E.

V-H-F Bridge for Impedance Measurements Between 20 and 140 Megacycles, by Robert A. Soderman of General Radio Co.

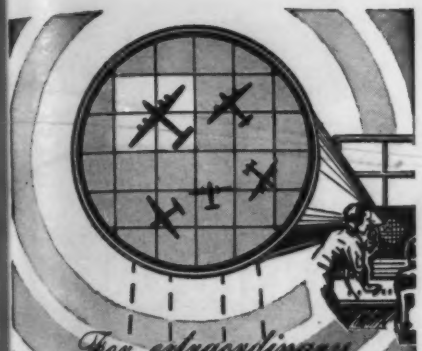
6:30 P.M.—Group Dinner

8:15 P.M.—Photographic Session; Chairman—A. L. Schoen:

The Problem of Amateur Color Photography, by Ralph M. Evans of Eastman Kodak Co.

Network Projection Television

DEVELOPMENTAL equipment that produced television pictures 6 by 8 feet in size on a beaded screen was demonstrated at the Atlantic City NAB convention by engineers of the Radio Corporation of America. The projector, suitable for accommodation of overflow crowds at conventions and for theater television,



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Features

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Solderlite

The new Weller Soldering Guns with Solderlite plus the fast 5 second heating help make service work more profitable for radio, television and appliance service men, electrical maintenance men, electric motor rewinding and repair shops automotive electrical service.

A useful and time-saving tool for laboratory workers, experimenters, hobbyists, telephone installation and maintenance men. S107 100 watts single heat, D207 100/135 watts dual heat.

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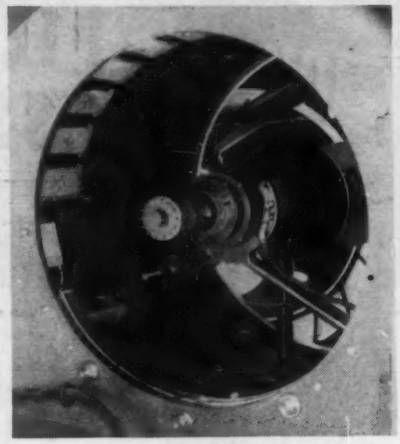


Experimental large-screen projection system depends on 7-inch cathode-ray tube

comprises a reflective optical system and experimental cathode-ray tube. The optical system, comparable to a conventional f/2 projection lens but transmitting about six times the light, consists of a 21-inch spherical mirror and a 14-inch aspherical correcting lens mounted vertically in a tubular housing. The 50,000-volt cathode-ray tube has a 7-inch screen coated with new types of phosphors that produce white light; metal backing is used. The electron gun and internal tube construction are modified to withstand the high voltage. An r-f power supply is used. Program material, originating at WNBT, New York, was relayed via Philco facilities at Mt. Rose, N. J., and Wyndmoor, Pa. to RCA relays at Philadelphia, Blue Anchor, and Batsto, N. J., reaching Atlantic City at the end of the 200-mile microwave link.

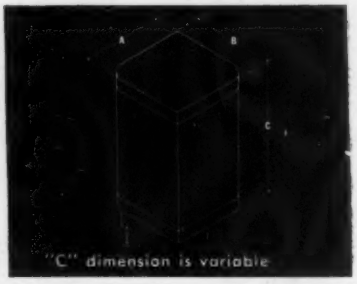
Automatic Flight Controller

AS AN extension of pushbutton flying, the All Weather Flying Division of the Air Forces recently demonstrated publicly a completely automatic flight sequence controller by flying across the North Atlantic. The controller is set to make the plane take off, fly a specified route (series great circle rhumb lines) and land at its destination.

Although the controller itself is an electromechanical unit, it operates in conjunction with such electronic equipment as the familiar instrument landing system for takeoff and approach, an electronic autopilot, and a magnetically sta-

OLYMPIC
STANDARD
TRANSFORMER
CASES

Now available in quantity, OLYMPIC standardized transformer cases are specifically designed to meet all normal requirements where standard cases are used. Construction is rigid, with rounded corners, and tight-fitting covers top and bottom. OLYMPIC standard transformer cases can be furnished with pierced covers, studs, brackets or channels. Inquiries are invited—write for illustrated bulletin—no obligation.



CORE	CASE	A	B	C
E1-21	1	1¾"	1½"	2⁹⁄₁₆"
E1-625	2	1⅞"	1⅞"	2⁹⁄₁₆"
E1-75	3	2¼"	2⅛"	2¹³⁄₁₆"
E1-11	4	2⅝"	2½"	3³⁄₃₂"
E1-12	5	3"	2⅞"	3³³⁄₃₂"
E1-3A	6	3¼"	3"	3¹⁵⁄₃₂"
E1-112	7	3⅜"	3¼"	4³⁄₃₂"
E1-125	8	3⅜"	3½"	4¹⁵⁄₃₂"
E1-137	9	3⅞"	3⅞"	4²⁷⁄₃₂"
E1-13	10	4⅜"	4¼"	5¹¹⁄₃₂"
E1-151	11	5"	4⅜"	5¹⁵⁄₃₂"
E1-36	12	5⅜"	4¾"	6¹⁵⁄₃₂"

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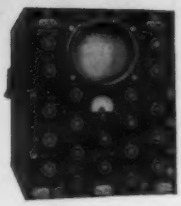
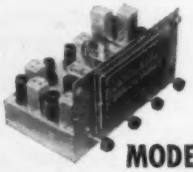


Versatile, Precision OSCILLOSCOPE MODEL OL-15

This is a highly flexible instrument particularly adaptable for production testing or research work in television, radar, facsimile work, and radio-frequency equipment.



MODEL RJ-12 FM-AM TUNER

An easy-to-install highly-sensitive tuner that provides distortion-free reception on FM and quality reception on AM. Tuning eye shows correct tuning. One antenna serves both FM and AM. Many other features. Armstrong circuit.

WWV FREQUENCY CALIBRATOR

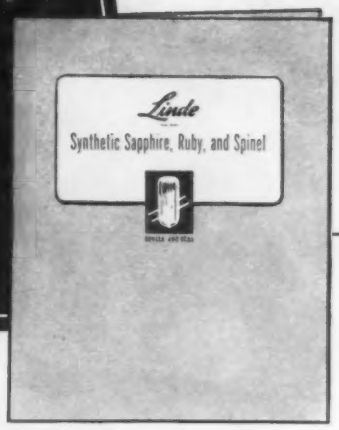
Full, accurate use of station WWV, the world's finest primary frequency and time standard, is obtained from the Browning Model RH-10 Standard Frequency Calibrator.

WRITE FOR LITERATURE

OTHER EQUIPMENT manufactured by Browning Laboratories includes an accurate frequency meter and ECO Model MJ-9, for operating in the Ham bands, and a frequency meter (Model S-4) especially designed for checking mobile transmitters.

BROWNING LABORATORIES, INC.
WINCHESTER, MASS.

DESIGN ENGINEERS— *send for this booklet!*



If you are concerned with material specifications you'll want this 28-page booklet . . . because LINDE synthetic sapphire is a material for key parts on which successful operation of a whole machine can depend.

This booklet describes the successful uses of this material, the properties, and the forms and grades available. It's full of pertinent illustrations, including a picture-caption story of fabricating techniques.

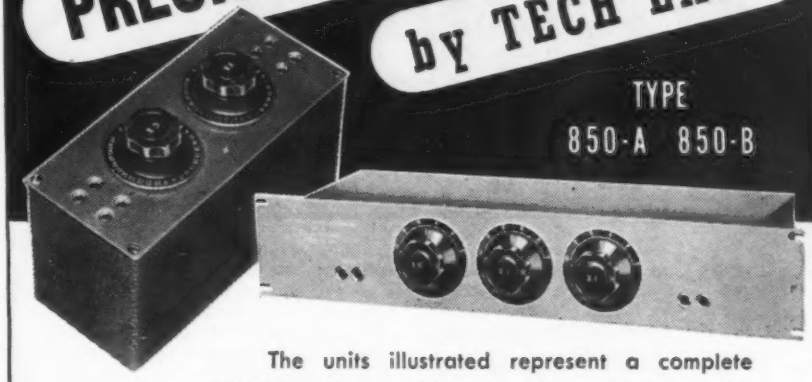
Send for this booklet on your letterhead. Ask for Booklet 4-B—today!

The word "Linde" is a trade-mark of The Linde Air Products Company

THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide and Carbon Corporation
30 E. 42nd St., New York 17, N. Y. UCC Offices in Other Principal Cities
In Canada: DOMINION OXYGEN COMPANY, LIMITED, Toronto

NEW...IMPROVED PRECISION ATTENUATORS by TECH LABS

TYPE 850-A 850-B

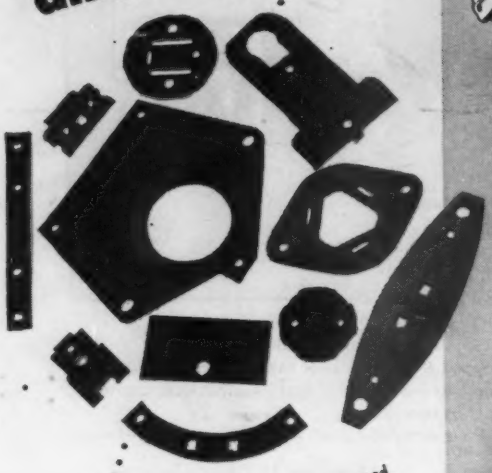


The units illustrated represent a complete redesign of our older precision attenuators for laboratory standards. Flat for all frequencies in the audio range. Reasonably flat to 200 k.c. up to 70 db.

Bulletin sent on request.

TECH LABORATORIES, INC.
Manufacturers of Precision Electrical Resistance Instruments
337 CENTRAL AVE. • JERSEY CITY 7, N. J.

Baer* can supply your vulcanized and phenol fibre fabrications



SEND BLUEPRINTS AND SPECIFICATIONS—NO OBLIGATION!

When you use these tough, lightweight and inexpensive parts, you build their many advantages *into your own product.* Fabricated to order, BAER FIBRE washers, special shapes, terminal boards, and other parts are accurately and uniformly produced to specification in any quantity. Selection of grades by physical and electrical qualities, permits application to a wide range of operating conditions and requirements. Investigate now!

LITERATURE ON REQUEST

N. S. BAER COMPANY

MONTGOMERY ST., HILLSIDE, N. J.

*Baer fibre is versatile ... can be stamped, punched, drilled, tapped, milled, sheared, sawed and shaved to specification.

LEADERSHIP ALL THE WAY!

60 kc. to 75,000 kc. CRYSTALS

Subsonic and Ultrasonic

X-cut circular crystals up to 3" diameter and square crystals up to 2" on a side, in thicknesses from 2" to .005" with frequencies from 60 kc. to 20,000 kc., optically finished or silver, gold, or nickel-on-gold plated.

RH-51 — **RH-241**

The wide range of Reeves-Hoffman crystal activities includes such crystal units as RH-51 a hermetically sealed, 1000 kc. crystal unit designed for frequency meters and secondary standards. The metal tube holder has a standard octal base.

In still another field of crystal applications is the RH-241 crystal unit designed for FM transmitters and receivers. This is a plated, 200-1000 kc., wire mounted, sealed unit which is also suitable for use in frequency meters and filters.

REEVES-HOFFMAN CORPORATION

SALES OFFICE: 215 EAST 91 STREET, NEW YORK 28, N. Y.

PLANT: 321 CHERRY STREET, CARLISLE, PA.

Instrument panel of the electromechanical predetermined flight controller is shown aboard the C-54 Skymaster, which made a trans-Atlantic round trip flight in September and October between Newfoundland and England

bilized gyro-compass. The controller regulates engine power for takeoff and cruising, adjusts trim, and performs all the integrated operations usually done by pilot, flight engineer, and navigator.

Using similar equipment the All Weather Flying Division has made two flights daily irrespective of weather conditions between Ohio and Maryland. Such equipment as this will relieve pilots of much flying routine, enabling them to monitor the flight of their planes more fully and observe flight conditions in greater detail and thereby assuring greater safety.

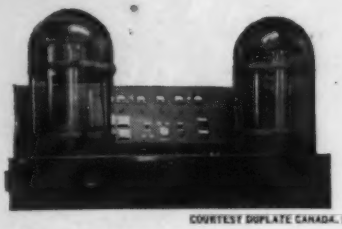
Televising Surgical Operations

TELEVISION broadcasts of operations performed in the operating room of the New York Hospital were presented to surgeons at the Waldorf-Astoria as an indication of the possible application of television to surgical education. These telecasts, with running commentary by the operating surgeon and his assistant, were made available to 5,000 surgeons attending the Clinical Congress of the American College of Surgeons on September 12. By this means, each surgeon had a view comparable to that which he might have had from the side of the operating table. This was the first time that televised

Silicone News

DC SILICONES

SILICONE DIFFUSION PUMP FLUIDS
Improve Adhesion of Metal Films

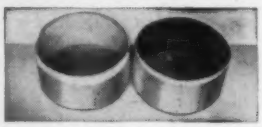


COURTESY DUPLATE CANADA, LTD.

Use of DC 703 in production units for the thermal evaporation of metallic and non-metallic films indicates that the exceptional heat stability of this DC Silicone Diffusion Pump Fluid results in better adhesion of magnesium fluoride films to glass.

After using DC 703 for the past year in two production units for evaporating magnesium fluoride and rhodium, Dr. Bateson of Duplate Canada Ltd., Oshawa, Ontario, reports that he has had no difficulty in producing equal or higher vacuum with pumping speeds equal to those of a high grade organic pumping fluid.

Even more significant are Dr. Bateson's observations that backstreaming seems to be reduced by use of DC 703; that the Silicone-vapor which does migrate into the system is more heat-stable; and that primary adhesion of magnesium fluoride films to glass is therefore improved. Preliminary observations also indicate that use of DC 703 results in brighter first surface mirrors.



That DC 703 causes less contamination of the system is further indicated by these aluminum shields. Both were normally exposed to the heaters in the bell jar for 9 months. Shield at left, exposed to DC 703, is quite clean. The other shield, exposed to a high grade organic pumping fluid, is covered with a dark brown deposit.

May we also remind you of DC 702. Both DC 702 and DC 703 are useful in electron microscopes, high vacuum dehydration and in evacuating electronic tubes. Write for pamphlet No. N9-4.

DOW CORNING CORPORATION
MIDLAND, MICHIGAN
New York • Chicago • Cleveland • Los Angeles
In Canada: Fiberglas Canada, Ltd., Toronto
In England: Albright and Wilson, Ltd., London

Dow Corning
FIRST IN SILICONES

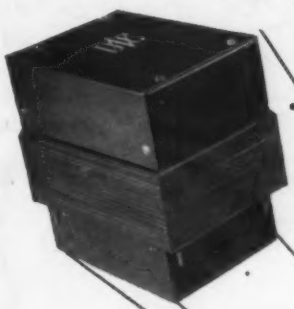
ABSOLUTE RESOLUTION
OF 0.06%
for Pressure Measurement

Fairchild Precision Linear Potentiometer

This is actual performance data of Fairchild's low torque Linear Potentiometer—a small precision instrument of 5,000 ohms overall resistance. *Application:* Telemetering extremely accurate electrical pressure measurements from 0" to 100" Hg abs. *Sensitivity:* Absolute resolution of 0.06% (from 1,600 turns on a single-turn mandrel) and 0.12% linearity. *Dependability:* Sustained linearity over several million pressure fluctuations. *Construction:* Precision engineered for quantity production with long-life gold, platinum and silver alloy contacts. For complete data address: Dept. 'F', 88-06 Van Wyck Boulevard, Jamaica 1, New York.

Fairchild CAMERA AND INSTRUMENT CORPORATION

TOP PERFORMANCE *with*— DINION
Transformers and Coils



Plan for performance perfection. For transformers and electrical coil windings of superior quality and production, use Dinion Transformers and Coils. Manufactured to specification or designed to meet particular requirements. Special or mass production.

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HIGH CAPACITY TO SPACE RATIO

With Johnson Pressurized Capacitors

JOHNSON Pressurized Capacitors are so carefully engineered that they provide the desired capacity and voltage rating with minimum pressure and condenser height. Because of their efficient electrical and mechanical design, they also provide the utmost in stable operating conditions.

Available as "standard" are variable, fixed and fixed-variable units — in a wide variety of capacitance and current rating. In addition, JOHNSON can build any pressure condenser to individual specifications.

FEATURES

- Low Loss
- High KVA Rating
- Shielded From External Electrostatic Fields
- Low Internal Distributed inductance
- Complete Dependability

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JOHNSON

a famous name in Radio!

E. F. JOHNSON CO. WASECA, MINN.

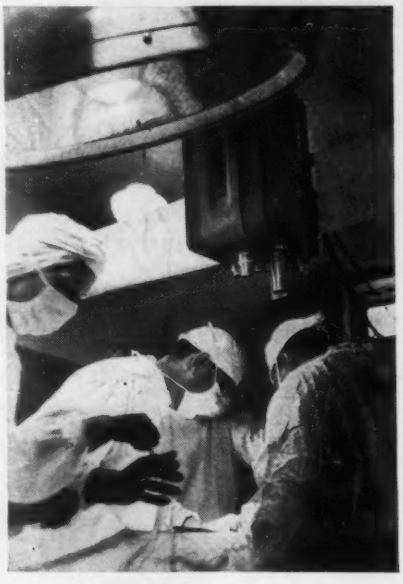
pictures of surgical operations were transmitted from an operating room in one location to television receivers in another part of the city.

For these telecasts, two local receivers were installed at the hospital. One of these was located in the operating room to enable the surgeon to see the operative area covered by the camera and to permit positioning the camera so as to prevent obstruction of the view. The other receiver was located in an adjoining office for the benefit of some members of the hospital staff.

The operating-room microphone was connected with a foot switch so that the operating surgeon could make comments at will. Because some surgeons prefer not to talk while operating, an auxiliary microphone is provided in the adjoining office so that the commentary can be delivered by another person.

Seven RCA Victor television receivers were installed in the hotel where seating facilities were provided for about 300 surgeons at a time. Pictures were transmitted via a 2-mile, 7,000-mc radio link between the roof of a nine-story extension of the hospital building and the 18th-floor terrace of the hotel.

Paraboloid-reflector antennas were used for both transmitting and receiving. Transmission was thus confined to a narrow beam, in-



The three-lens television camera, requiring no special lighting, is installed on a track above the operating table. The microphone mounted just behind the camera picks up the running commentary of the operating surgeon. RCA equipment was used

SUPERIOR ELECTRONIC PRODUCTS

used in the

GUN STRUCTURE OF TELEVISION TUBES

ANODE AND GRID CYLINDERS—

Straight cut, angle cut or rolled edge *Tubing* produced to very close tolerances.

DISC CATHODE ASSEMBLY—

Precision made and laboratory controlled to assure correct emission and cut-off characteristics.

The expanding television industry has turned to Superior's Electronic Division for the *conception* and *production* of these vital parts within the television tube.

THE BIGGER NAME IN SMALL TUBING Superior TUBE COMPANY

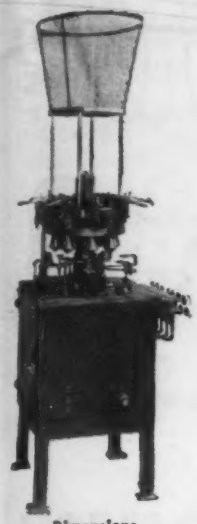
ELECTRONIC DIVISION

2500 GERMANTOWN AVENUE

NORRISTOWN, PENNA.

BAACH-INTERNATIONAL

EIGHT HEAD HOT-CUT FLARE MACHINE



Dimensions 24"x24"x72" high

- Automatic throughout.
- Can be synchronized with automatic Stem machine.
- Cuts off and flares in one operation.
- Production 1250 flares per hour. For miniature flares, fluorescent starters, standard size lamps, fluorescent and radio tubes.

RANGE OF MACHINE

Glass tubing 27 to 45 gauge

Length of flares 5 mm. to 80 mm.

Forms flares up to 47 mm. diam.

Net weight, 960 lbs. Gross weight 1450 lbs.

INTERNATIONAL MACHINE WORKS

Manufacturers of High Vacuum Pumps, Automatic Machinery for Incandescent Lamps, Electronic Tubes since 1916.

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Cellusuede FLOCKED-FILM

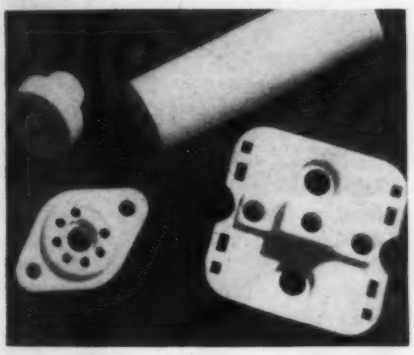
. . . the Solution to Many Finishing Problems

In instances where spraying Cellusuede Flock is not entirely practical, you will find flocked-film ready to do the job simply and effectively. Cellusuede Flocked-film is a pliant surface (of varying degrees of flexibility to meet certain conditions) evenly coated with millions of tiny flock fibres.

Film can be die-cut to meet specifications, and is easily applied with suitable adhesives. Sound deadening gaskets, box interior coatings, mar-proofing of external surfaces, and light-absorbing trim for backs of radio dials are but a few examples how Cellusuede Flocked-film can be used.

Precision-cut from new rayon filament in a wide range of lengths, Cellusuede Flock serves to increase the market value of thousands of products. Write today for booklet, color card, samples, prices, and other details.

CP Cellusuede Products, Inc.
ROCKFORD, ILLINOIS



Lavite STEATITE CERAMIC

Properties and Characteristics of Our LAVITE 51-5 Steatite Ceramic Body

Compressive Strength	98,000 lbs.	per square inch
Tensile Strength	7,200 lbs.	per square inch
Flexural Strength	10,500 lbs.	per square inch
Modulus of Rupture	20,000 lbs.	per square inch
Dielectric Strength	235 volts	per mil
Dielectric Constant	6.42	Frequency of 1 megacycle
Loss Factor	2.90	
Power Factor	.448	
Bulk Specific Gravity	2.664%	
Density (from above gravity)	0.096 lbs.	per cubic inch
Hardness (Mohr scale)	7.0	
Softening Temperature	2,350° F.	
Linear Coefficient of Expansion	8.13x10—6	
Moisture Absorption (ASTM D-116-42-A)	0.009%	

Design engineers and manufacturers in the radio, electrical and electronic fields are finding in LAVITE and precise qualities called for in their specifications . . . high compressive and dielectric strength, low moisture absorption and resistance to rot, fumes, acids, and high heat. The exceedingly low loss-factor of LAVITE plus its excellent workability makes it ideal for all high frequency applications.

We will gladly supply samples for testing.

D. M. STEWARD MFG. COMPANY
Main Office & Works: Chattanooga, Tenn.
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ENGINEERED FOR EFFICIENT FM AND TELEVISION RECEPTION

Magic Wand Aerials for FM and television offer electrical efficiency possible only through the enthusiastic teamwork of Ward's top-drawer experimental laboratory, and production facilities.

As the world's largest producer of aerials for car and home, Ward also is pioneering in educating 33 million present, and prospective, FM and television receiver owners that a good outdoor dipole antenna is necessary if quality reception is to be enjoyed. Watch for our hard-hitting ads in the Saturday Evening Post and leading newspapers.

In addition to developing outstanding FM, television and automotive aerials, Ward also has design and production capacity available to take care of special aerial needs. Submit your aerial problems to us now for an efficient, and economical, solution.

WARD Magic Wand FM AND TELEVISION AERIALS

As Advertised in the Saturday Evening POST

THE WARD PRODUCTS CORP.
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Division of The Gabriel Company
EXPORT DEPT.: C. W. Brandes, Mgr., 4900 Euclid Ave., Cleveland 3, O.
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WORLD'S LARGEST MAKER OF AERIALS FOR CAR AND HOME

suring privacy for these telecasts, which were of a nature not suitable for public view. With this system, line-of-sight transmission is possible over a distance as great as 30 miles.

The microwave relay transmitter passed a video bandwidth of 8 mc as compared with the usual transmitter video bandwidth of only 4 mc. Standard receivers having a 5-mc bandwidth were used. With this combination of equipment, it was possible for the surgeons to see pictures having better definition than those seen by the viewer of ordinary telecasts.

Clinics, operative and nonoperative, in hospitals are the principal means of video education in surgery. Since the accommodations for observers in operating rooms are limited, television provides a teaching medium that can serve large numbers of surgeons in class rooms and at conventions.

X-Ray Conference

FOUR PAPERS dealing with Geiger-counter x-ray spectrometer studies are on the program of the Fifth Annual Pittsburgh Conference on X-Ray and Electron Diffraction, scheduled for Nov. 7 and 8 at the Mellon Institute and the University of Pittsburgh. Registration begins at 9:00 a.m. Nov. 7 in the foyer of Mellon Institute. Papers that morning start at 9:40 and deal with interstitial compounds, while papers for Saturday morning start at 9:00 a.m. and deal with lattice imperfections and general subjects. Other papers, more likely to interest electronic engineers, are as follows:

2:00-5:00 p.m. Nov. 7—X-Ray and Electron Diffraction Studies at High Temperatures

(1) Some Results of High Temperature Studies, by H. F. McMurdie of NBS

(2) A Comparison of Crystal Structures of Ten Wrought Heat-Resisting Alloys at Elevated Temperatures with their Crystal Structures at Room Temperature, by J. H. Kittel of NACA

(3) Design Problems in High Temperature X-Ray and Electron Diffraction Cameras, by J. W. Hickman, E. A. Gulbransen, and R. J. Bertl of Westinghouse

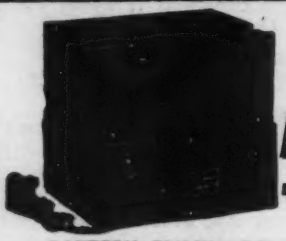
(4) High Temperature X-Ray Camera Design Using Induction Heating, by J. W. Edwards, R. Speiser, and H. L. Johnston of the Cryogenic Laboratory, Ohio State University

(5) An Electron Diffraction Study of Oxides Formed on Copper-Nickel Alloys at Elevated Temperatures, by J. W. Hickman of Westinghouse

(6) The Interpretation and Use of Electron Diffraction Studies on Metals at High Temperatures, by E. A. Gulbransen of Westinghouse

2:00-5:00 p.m. Nov. 8—Symposium on

CURRENT CONVERSION WITH ATR QUALITY PRODUCTS



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BATTERY ELIMINATORS
For DEMONSTRATING and TESTING AUTO RADIOS

New Models . . . Designed for Testing D.C. Electrical Apparatus on Regular A.C. Lines. Equipped with Full-Wave Dry Disc Type Rectifier, Assuring Noiseless, Interference-Free Operation and Extreme Long Life and Reliability.

- Eliminates Storage Batteries and Battery Chargers.
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- Type 60-ELIA . . . Rated Output 6.3 Volts at 6.5 Amperes. Dealer Net Price $22.80
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ATR AUTO RADIO VIBRATORS

Designed for Use in Standard Vibrator-Operated Auto Radio Receivers. Built with Precision Construction for Longer Lasting Life. Prices are app. 15% lower.

ATR STANDARD AND HEAVY DUTY INVERTERS

For Inverting D. C. to A. C.
Specially Designed for Operating A.C. Radios, Television Sets, Amplifiers, Address Systems, and Radio Test Equipment from D.C. Voltages in Vehicles, Ships, Trains, Planes and in D.C. Districts.

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Quality Products Since 1931
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Lektromesh . . . the new, one-piece solid metal-plated screen is made by electrodeposition . . . supplements rather than competes with woven wire. Continuous production methods permit runs of 100 foot rolls up to 35 inches in width of 40 to 120 mesh . . . meshes 150 to 400 in smaller units . . . and is furnished in nickel and copper. This unique product presents a smooth surface and is readily fabricated by stamping, welding and soldering. Combining accuracy and uniformity of openings with the smoothness of perforated metals, Lektromesh applications are unlimited. Ideal for strainers in fuel systems, dry-screening and a large number of specialized items. Distinct value lies in its even plane surface that withstands wear when exposed to doctor blades and scrapers as in continuous filters and its unique ability to screen material with minimum clogging.

Lektromesh folder and small sample available. Write Dept. L-201

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WIRE PRODUCTS Jelliff SINCE - 1680

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MYCALEX

LOW LOSS INSULATION

Where high mechanical and electrical specifications must be met.

For *Complete* Catalog and Specifying information on MYCALEX 400, K, & 410 refer to pages 84-85 in the 1947 Mid-June

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Potentiometer Toroidal Type

For use in electrical computers, servo systems and other control circuits where 360° rotation, high precision and low noise levels are essential.

Can be supplied in a wide variety of styles within linear resistance ranges from 500 to 20,000 ohms—Linearity ±.3%; enclosed toroidal wound, low torque, electrical angle 360° or less. Capable of rotation through angles greater than 360°.

SPECIAL FEATURES: Capability of continuous rotation—Accuracy of linearity—Wide variety of contact and tapping arrangements—Durability, the RL-210 type (6000 ohms, 2 brushes) showed no serious wear nor measurable departure from initial characteristics following over one million revolutions at speed of 20 RPM—Overall diameter 3 15/16", height 2 15/16".

Write for Bulletin F-68

THE GAMEWELL COMPANY

NEWTON UPPER FALLS 64, MASSACHUSETTS

Crystals for the Critical

"STABILIZED"

JK STABILIZED OVEN

Range 80 to 7500 kc. Standard five prong base. Octal on special order. Approved by the FCC for BC stations. Can be supplied in hermetically sealed, pressure mounted, plated and wire mounted crystals. Also with variable micrometer air gap mounting to give exact frequency adjustment. Plus or minus 1 degree C maintained. 6.3 v. heater unit; others on special order. Current is approx. 1 ampere at 6.3 v. Molded phenolic body. Also available without thermometer or without side terminal.

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SANDWICH, ILLINOIS

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FOR THE

Manufacturers of 7-pin and 9-pin miniature tube—radios and equipment

#JE-9 (9-pin)—#JE-10 (7pin)—Star Miniature socket wiring plugs for accurate alignment of miniature socket contacts during wiring. Precision cast of zinc base alloy—pins of stainless steel.

#JE-15 (9-pin)—#JE-13 (7-pin)—Star Miniature tube pin straighteners (with stainless steel insert) to obtain a perfect fit when the tube is placed in the equipment.

Scientifically designed—Precision made

READY FOR IMMEDIATE DELIVERY IN ANY QUANTITIES

STAR EXPANSION PRODUCTS CO. INC.

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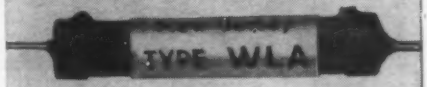
IN-RES-CO WIRE WOUND RESISTORS

WL 5/8—5/8" x 3/16" (Radial Lead) .01 Ohms min. 3,000 Ohms max.
WLA 5/8—5/8" x 3/16" (Axial Lead) .01 Ohms min. 3,000 Ohms max.



WL—1" x 3/16" (Radial Lead) .01 Ohms min.
WLA—1" x 3/16" (Axial Lead) 10,000 max.

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Here's a new line of resistors priced for real economy. Wire wound to a tolerance of 1% — higher accuracy on special order at slightly higher cost. Write today.

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APPLICATION-DESIGNED RESISTORS!

Quality you can see!

PREMIER DIALS, PANELS & PLATES

What counts, sales-wise, is what your customer sees. What gets the attention for Premier Metal Products, quality-wise, is their sharpness and clarity . . . close tolerances . . . rich colors and baked-in finishes. Let us tell you how these qualities can add important sales-appeal to your products.

Etched & Lithographed on:

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The New AMPLICALL is no ordinary "intercom system." Dramatically different in its impressive styling, definitely advanced in functional design, the New AMPLICALL serves the intercommunication needs of business and industry as they have never been served before. Apart from exceptional fidelity of speech reproduction, the New AMPLICALL incorporates a number of exclusive advantages in operation and installation which sets it apart in the intercommunication field. New AMPLICALL Systems are available to meet every conceivable business communication requirement throughout business and industry. Write today for full information covering America's Finest Business Communication Systems.

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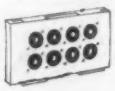
Featuring:

"BUSY" Signal—visual type using neon bulb to indicate instantly when station being called is busy.



PLUG-IN Masters—for quick, easy exchange or transfer of Master units when desired.

HANDSET—professional type for private conversation — optional equipment with Masters.

Rauland

Geiger-Counter X-Ray Spectrometer Studies

(1) Application of X-Ray Analyses to Ceramic Clays, by G. L. McCreery of The Ohio Brass Co.

(2) Application of Geiger-Counter Spectrometer to the Measurement of Particle Size, by L. E. Alexander and E. Kummer of Mellon Institute

(3) Quantitative Organic Analysis with the Geiger-Counter X-Ray Spectrometer, by C. L. Christ, R. B. Barnes, and E. F. Williams of American Cyanamid

(4) Geometric Factors Affecting the Contours of Geiger Spectrometer Maxima, by L. E. Alexander of Mellon Institute

(5) The Photomultiplier Radiation Detector, by Fitz-Hugh Marshall and J. W. Coltman of Westinghouse

Second Annual Instrument Conference

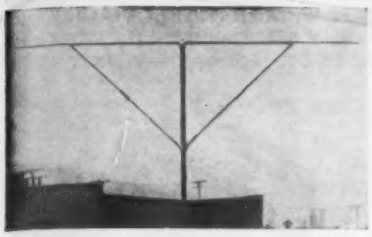
MORE THAN 7,000 engineers and technicians, nearly double last year's attendance, registered at the Instrument Society of America Conference and Exhibit in September. Held at the Stevens Hotel in Chicago, the exhibition attracted 139 manufacturers of equipment who showed six million dollars worth of equipment.

Newly elected officers for 1947-48 are: president, Paul G. Exline, section engineer, Gulf Research Corp., Pittsburgh; vice-president, H. C. Frost, assistant director of engineering, Chemical Division, Corn Products Refining Co., Argo, Illinois; vice-president, F. H. Trapnell, instruments engineer, E. I. duPont de Nemours Co., Wilmington, Del.

Carry-over officers who are serving the second year of a two-year term are: first vice-president, Prof. Carl P. Kayan, Department of Me-

Paul G. Exline of Gulf Research Corporation, new president of ISA

PREMAX



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Cover all frequencies between 44 and 216 mc. with ONE low-cost, light-weight Antenna! Gives excellent response for all television and FM bands. Requires 15% less space than any other conventional dipole.

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103

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NEW! More Comfortable Grip!

Have your dealer show you the new XCELITE screw driver! See how it helps you work easier, faster. Feel the smooth, comfortable, SURE-GRIP genuine XCELITE handle—mar-proof, break-proof, shock and fire resistant! Husky CHROME VANADIUM BLADE, precision ground on flat belt to fit screw slot snugly. XCELITE is the choice of experts. You'll use it many efficient years! Order now!

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Metal Work of Every Description

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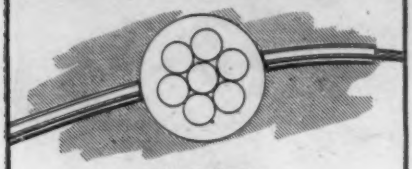
THERMOPLASTIC INSULATED
RADIO HOOK-UP WIRE



Type SRIR

Approved by the Army-Navy Electronics Standards Bureau (under Spec. JAN-C-76) for Radio Hook-up use where the voltage does not exceed 1,000 V. Sizes: 24 Solid to 6 Stranded.

Recommended for communications and industrial electronic control applications, this wire has proved to be superior to push-back and rubber insulated types because the Synkote insulation is almost totally impervious to water, oils, acids, alkalies, sunlight, cold, and fungus growths. It is vermin-proof, unusually resistant to abrasion, flexing, and tearing, and will not support combustion. In addition, it has extremely high dielectric breakdown strength and low dielectric leakage. In tests performed by the Bureau of Ships, TYPE SRIR did not break down under 12,000 V.

To cut out interfering fields, it can be shielded to any specifications with a braid of tinned or bare copper, woven (loose or tight) to any specified degree of coverage. Gauge of shielding strands varies according to individual requirements.

Other, standard, approved, Synkote Radio Hook-up Wires: Types SRHV, WL, and (Underwriters' Approved) TF, TFF, and Appliance Wiring Material are available in both small and large quantities — shielded, if desired, to any specifications.

Many other types of Hook-up Wire, to meet special requirements, can be manufactured on short notice — in practically any quantity. For complete information, consult our Engineering Department.

Synkote Antenna Wire, and Two-conductor Parallel Cord (with solid, unbreakable, molded plug) are also available.

All Synkote wire has unusually tough, practically age-proof insulation.

*Reg. U.S. Pat. Off.

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Factory: Hamburg, N. J.

chanical Engineering, Columbia University, New York; vice-president, Herbert H. Barnum, H. H. Barnum Co., Detroit; treasurer, Hugh E. Ferguson, Peoples Gas Light and Coke Co., Chicago; and executive secretary, Richard Rimbach, Instruments Publishing Co., Pittsburgh.

A considerable number of the instruments exhibited utilize electronic tubes and a number of the technical papers delivered at the technical session contained references to electronic equipment. These included an electronic potentiometer used in turbine testing, an electronic dewpoint indicator for moisture measurement, a metals comparator, an oscillator circuit for Q-metric analysis, radio telemetering equipment for aircraft, and the automatic recording spectrophotometer as adapted for chemical concentration measurements.

F-M Rebroadcasting

NETWORK f-m broadcasting without use of long-distance telephone wire circuits was demonstrated to International Telecommunications Conference delegates at Atlantic City, N. J. recently. Programs originating in Dr. E. H. Armstrong's f-m station W2XMN-W2XEA at Alpine, N. J. were picked up by a special receiver at station WBAB-FM in Atlantic City, a distance of 116 miles, and rebroadcast to the delegates a few miles away. The demonstration showed that high-quality static-free f-m broadcasting in the 100-mc range is not limited to a 30-mile line-of-sight radius, but can be extended over much greater distances for rebroadcast purposes. The engineering involved in setting up the special high-fidelity receiving equipment and connecting it to the wire lines was carried out under the direction of S. L. Bailey of Jansky and Bailey, consulting engineers.

Changes in NBC's Television Personnel

TO SPEED development of NBC's nation-wide television network as

BUILDERS OF COMMUNICATIONS EQUIPMENT, MEASURING INSTRUMENTS FOR COMMERCIAL AND INDUSTRIAL USE, AND OTHER ELECTRONIC DEVICES — PRODUCTS WHERE PRECISION PERFORMANCE LARGELY DEPENDS UPON *TIME AS A FACTOR OF CONTROL* — KNOW THEY

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Cramer

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QUALITY
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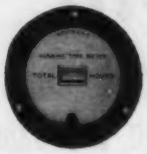

RUNNING TIME METERS
Synchronous motor driven. Register automatically and cumulatively total operating or idle time on circuits, machines, systems.

TIME DELAY RELAYS
Provide adjustable or fixed time delay between operation of a control circuit and subsequent opening or closing of a load circuit.

SYNCHRONOUS MOTORS
Permanent magnet type for applications requiring a constant speed at a given frequency. Small size. 30" ounce torque. Twenty-eight speeds from 60 rpm to 1/24 rph.

For a wide range of standard timers and controls.. or special adaptations for specific applications..consult R. W. CRAMER CO., Box No. 3, Centerbrook, Conn.

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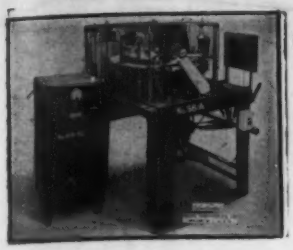

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Sizes ¼ To 250 KVA
SPOT WELDERS
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THE General Electric Decade Scaling Unit is the outstanding instrument in this field. The salient technical features of the equipment will recommend it as indispensable in modern research.

- Low Resolution Time . . . 0.1 microsecond.
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- Decade counting . . . direct interpolation.
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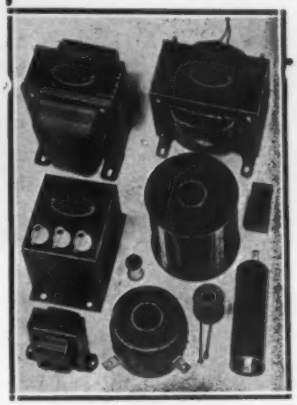
For complete information on the Decade Scaling Unit and other General Electric Laboratory Measuring Equipment write: *General Electric Company, Electronics Park, Syracuse, New York.*

GENERAL ELECTRIC

165-F3



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More than 20 years of special coil and transformer manufacturing for industry, laboratory, research and instrument makers.

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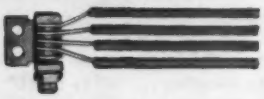


Vacuum-processed, gold-coated Bradley instrument rectifiers increase equipment efficiency. Especially designed for use where stability and permanence of calibration are important, "Coprox" rectifiers meet the most exacting requirements. Yet they cost no more than ordinary rectifiers — in most cases, less.

Temperature error is exceptionally low with Bradley rectifiers. Aging is practically nil. Pre-soldered leads. Rating of CX-2E series up to 4.5 volts A. C., 3 volts and 5 milliamperes D. C.

Illustrated literature, available on request, shows more models of copper oxide rectifiers, plus a line of selenium rectifiers and photocells. Write for "The Bradley Line."

BRADLEY LABORATORIES, INC.

82 Meadow St. New Haven 10, Conn.

well as its sight-and-sound programming, O. B. Hanson, vice-president and chief engineer, has been named to assist the executive vice-president in planning the technical phases of television. He will supervise the building and installation of new stations, interconnections, relays and other engineering facilities. Norman E. Kersta, director of television operations, will be in charge of broadcast operations of the television department.

George McElrath has been appointed director of engineering operations. He will manage the technical aspects of sound broadcasting.

Filling the new post of director of television engineering operations and reporting to N. E. Kersta is Robert E. Shelby, whose former position as director of technical development is now held by George M. Nixon.

BUSINESS NEWS

BART-MESSING CORP., manufacturers of the Sel-Rex selenium rectifiers, have a new plant over 6,000

New Bart-Messing Corp. plant

square feet in area at 45 Morgan Ave., Brooklyn, N. Y.

HERMON HOSMER SCOTT, INC., Cambridge, Mass., has been formed to provide increased manufacturing and engineering facilities for equipment employing the Dynamic Noise Suppressor, and is taking over the unfilled orders and inventory of such items from Technology Instrument Corp., Waltham, Mass.

PHILCO CORPORATION, Philadelphia, is offering formal licenses to all set manufacturers to use, subject to royalties, its approximately 700 patents and inventions in the radio

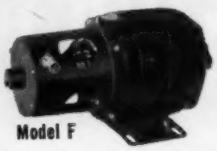
HERE ARE TWO EASTERN Single Stage Centrifugal Pumps

Model D-6 is a compact, lightweight centrifugal pump designed for continuous duty where small volume and pressure are required. Pump and motor are close-coupled. An open vane impeller is mounted on the motor shaft extension. Equipped with either an easily adjustable stuffing box or mechanical rotary seal, the pump proper has no bearings.

Size: 7½" x 4½" x 4¾"
Weight: 11½ lbs
Power: 1/30 HP
Alloys: Standard in Cast Iron, Bronze, Stainless Steel, Monel Metal, Hastelloy C. For quantity applications, available in other alloys.

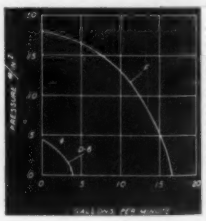
Model D-6

Model F is a heavy duty centrifugal pump designed for continuous operation in applications requiring sizeable volumes or pressures with a minimum of pump size and weight. The heavy duty General Electric ball bearing induction type motor may be totally enclosed for general use and explosion-proof for use with flammable liquids and vapors. This pump is of the close-coupled type, motor armature and pump impeller being mounted on the same shaft. It is available with either adjustable stuffing box or mechanical rotary seal.


Model F

Size: 11½" x 6½" x 6¾"
Weight: 35 lbs
Power: 1/3 HP
Alloys: Standard in Cast Iron, Bronze, Stainless Steel, Monel Metal and Hastelloy C. For quantity applications, available in other alloys.

Eastern Industries has engineered more than 300 models of small pumps for industrial use. In addition, Eastern's experienced engineering staff welcomes the opportunity to design pumps for special applications. For further information concerning any of the models in the well-known Eastern line, write for Bulletin 205. Please address all inquiries to Eastern Industries Inc., 296 Elm St., New Haven, Conn.



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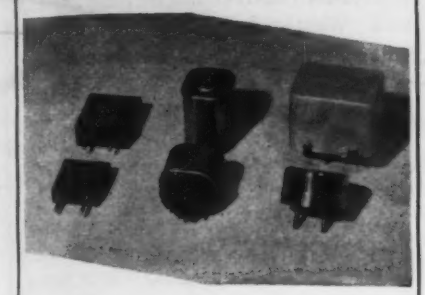
The New "LF" Series QUARTZ CRYSTAL UNITS



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- higher Q
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- quicker starting
- stable frequency
- moisture proof
- free from aging

Technical characteristics:

Frequency range:—50 kc to 500 kc
Frequency calibration—.01% to .002%
Temperature coefficient—1cy/mc/°C
Mounting—pressure mounted between pins which resonate at the crystal frequency
Holder (hermetically sealed types)—all metal
Holder (temperature controlled types)—low loss phenolic base with spun aluminum cover
Electrodes—nickel plating on silver base
Contacts (external)—standard 2 prong, 5 prong, octal base or lugs
Temperature control (optional)—6V heater, thermostatically controlled within ± 2°C—adjustable to any temp. 40°C to 75°C

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FEATURES: Carrier Frequency—50 kilocycles to 500 megacycles and up . . . Frequency Sweep—from 30 megacycles to 30 kilocycles throughout the complete spectrum . . . Continuously variable attenuator . . . Low amplitude Modulation while sweeping—less than 0.1 DB per megacycle . . . Precision wavemeter. Price $395. F.O.B. factory.

- **The MEGA-MATCH.** *Visual Display of Reflected Energy.*

10 to 250 MC and up. Completely electronic. No slotted lines, moving parts, bridges, or other frequency sensitive devices. Precision frequency meter. Saves engineering time. Presents instantly data which would take hours to tabulate. $695. F.O.B. factory.

- **The MEGA-MARKER.**

Precision variable marker oscillator having a range of 19 to 29 megacycles for the television i.f. band. Crystal oscillator for the FM i.f. band (10.7 mc). Dial provides over 12 inches of calibrated scale length. May be read to accuracies of 0.02 megacycles. $60. F.O.B. factory.

KAY ELECTRIC CO., 34 Marshall St., Newark 2, N. J.
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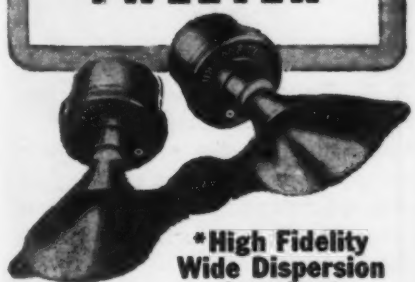
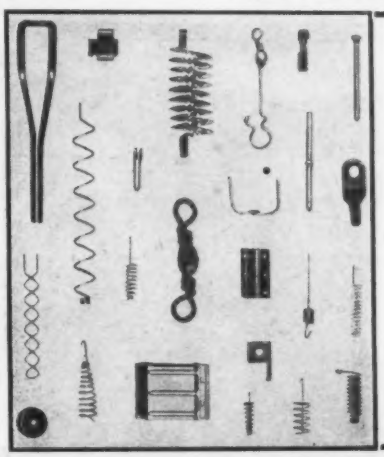
It's the new
UNIVERSITY TWEETER



***High Fidelity Wide Dispersion Low Cost**

It's the new UNIVERSITY Tweeter! Extends the range of any cone speaker to 15,000 cycles. Install it in your present equipment by merely attaching two wires to the voice coil terminals of the existing speaker, without creating any electrical unbalance. Simply connect, listen and enjoy. Twin units provide 100° horizontal and 50° vertical dispersion. Three models to choose from—walnut cabinet type, and single or dual unmounted types. Priced from $20.00. Write today for complete details to UNIVERSITY LOUDSPEAKERS, INC., 80 South Kensico Avenue, White Plains, N.Y.

University Loudspeakers



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Filaments, anodes, supports, springs, etc. for electronic tubes. Small wire and flat metal formed parts to your prints for your assemblies. Double pointed pins. Wire straightened and cut diameter up to ⅛-inch. Any length up to 12 feet.

LUXON fishing tackle accessories.

Inquiries will receive prompt attention.

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Compact...

PLUG-IN SENSITIVE RELAYS

NEW FEATURES OF THIS DESIGN:

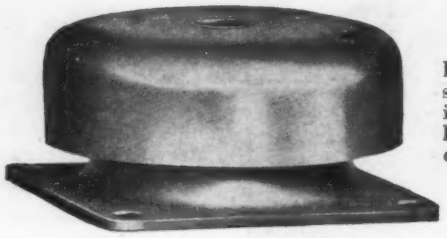
- Fits octal socket.
- Outline dimensions: 1¼" x 1¼" x 2" above socket.

Features of ALL SIGMA Series 41 Relays:

- DC sensitivity:—0.020 watts (min. input.)
- AC sensitivity:—0.1 volt-ampere (min. input.) One standard 110 volt AC model draws about 1.5 milliampere.
- Contact ratings up to 15 amperes on low voltage.
- High quality construction—mechanically rugged.
- Very low cost. A wide range of standard adjustments for this and other Sigma relays is now available—See your jobber or write direct.

SIGMA sales and engineering departments are ready to give your relay problems prompt analysis and action.

Sigma Instruments, INC.
Sensitive RELAYS
62 Ceylon St., Boston 21, Mass.



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For impact absorption and isolation of higher frequencies

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We offer a complete line of highly engineered Vibration and Impact isolators for commercial, industrial and military applications . . . also an Engineering consulting service on special problems.

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Formerly L. N. BARRY CO., INC.
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receiver, electrical phonograph, and television receiver fields. RCA, G-E, and Westinghouse have already been licensed by Philco.

ANDREW ALFORD, CONSULTING ENGINEERS, have moved their laboratory to 299 Atlantic Ave., Boston 10, Mass.

ASSOCIATION OF ELECTRONIC PARTS AND EQUIPMENT MANUFACTURERS has elected the following officers: Les A. Thayer of Belden Mfg. Co., Chicago, chairman; Charles Hansen of Jensen Mfg. Co., Chicago, vice-chairman; Helen Staniland of Quam-Nichols Co., Chicago, treasurer; Ken C. Prince, Chicago attorney, executive secretary.

PERSONNEL

JAMES R. RINKE is now chief engineer at Potter & Brumfield Manufacturing Co., Princeton, Indiana, manufacturers of electrical relays. He was formerly in charge of development of vibrator-type power supplies and converters at Electronic Laboratories, Inc. of Indianapolis.

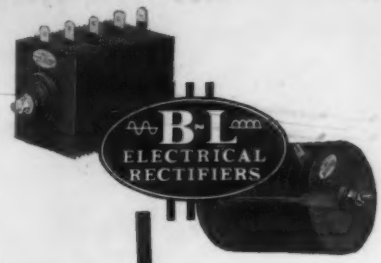
JAMES T. WATSON, former president of Meissner Mfg. Co. and until recently manager of the Meissner Division of Maguire Industries, is now a member of the board of directors of Potter & Brumfield Manufacturing Co., Princeton, Indiana, electrical relay manufacturers.

HENRY BUTZ was appointed chief engineer of the Nelson Electric Corp., Santa Monica, Cal.

R. C. MASON, on leave of absence from the atomic energy project in Oak Ridge for the past year, was named manager of the electro-physics department of Westinghouse Research Laboratories in Pittsburgh, Pa.

PAUL WEATHERS, after 16 years with RCA, is now vice-president and chief engineer of Airdesign, Inc. of Upper Darby, Pa.

HUGH L. DRYDEN has left the National Bureau of Standards to become director of research for the National Advisory Committee for Aeronautics. He played an important part in the development of the



From Milliwatts To Kilowatts

Selenium

Copper Sulphide

To simplify the solution of your AC-DC power requirements, Benwood-Linze offers you a quarter century of development and research experience in the field of metallic rectifiers and their application.

Tell us your problems. Consult us without obligation.

Manufacturers of Selenium and Copper Sulphide rectifiers, rectifier-transformer assemblies and AC-DC power supply units for every requirement.

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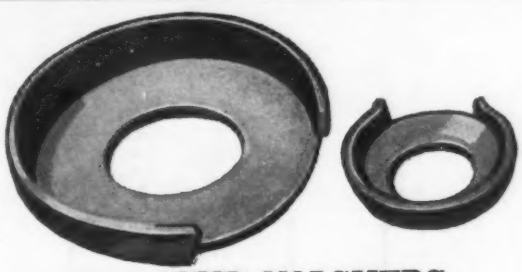

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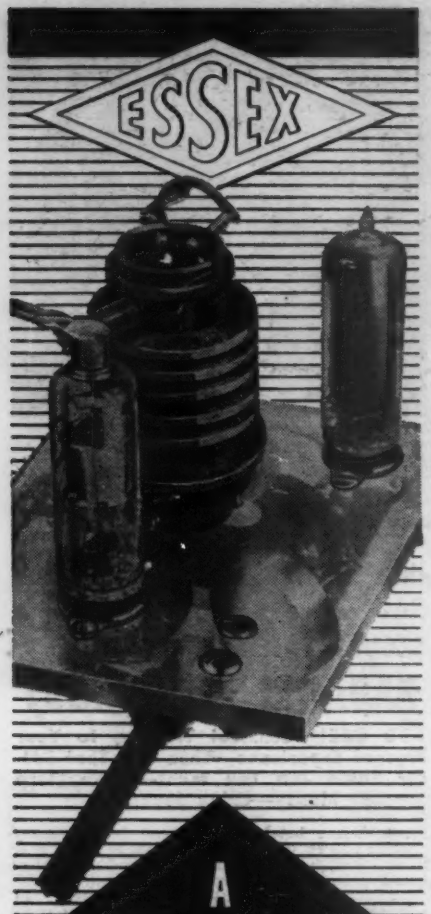

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A. A. WARD has been promoted from vice-president of Altec Lansing to vice-president in charge of manufacturing of the Altec Service Corp., New York City.

W. L. BARROW, at one time on the MIT electrical engineering staff, is the newly appointed chief engineer of Sperry Gyroscope Co., Inc., Great Neck, N. Y.

M. W. Scheldorf

W. L. Barrow

M. W. SCHELDORF, co-inventor of the circular-loop f-m antenna, after 19 years with General Electric, has joined Andrew Co., Chicago, as head of engineering research. He will be in charge of the development of new antennas, transmission lines, and other related items.

STANLEY GLASER was appointed manager of the radio section of the Crosley Division, Avco Manufacturing Corp., Cincinnati, Ohio.

WALTER REMBERG, who developed the vacuum-tube acceleration pickup which depends on the internal vibration of a vacuum tube to measure changes in acceleration of vibrating parts of an aircraft in flight, was appointed chief of the Mechanics Division of the National Bureau of Standards.

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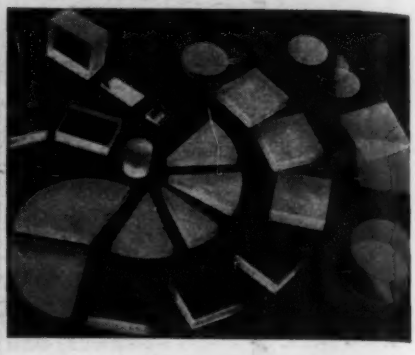

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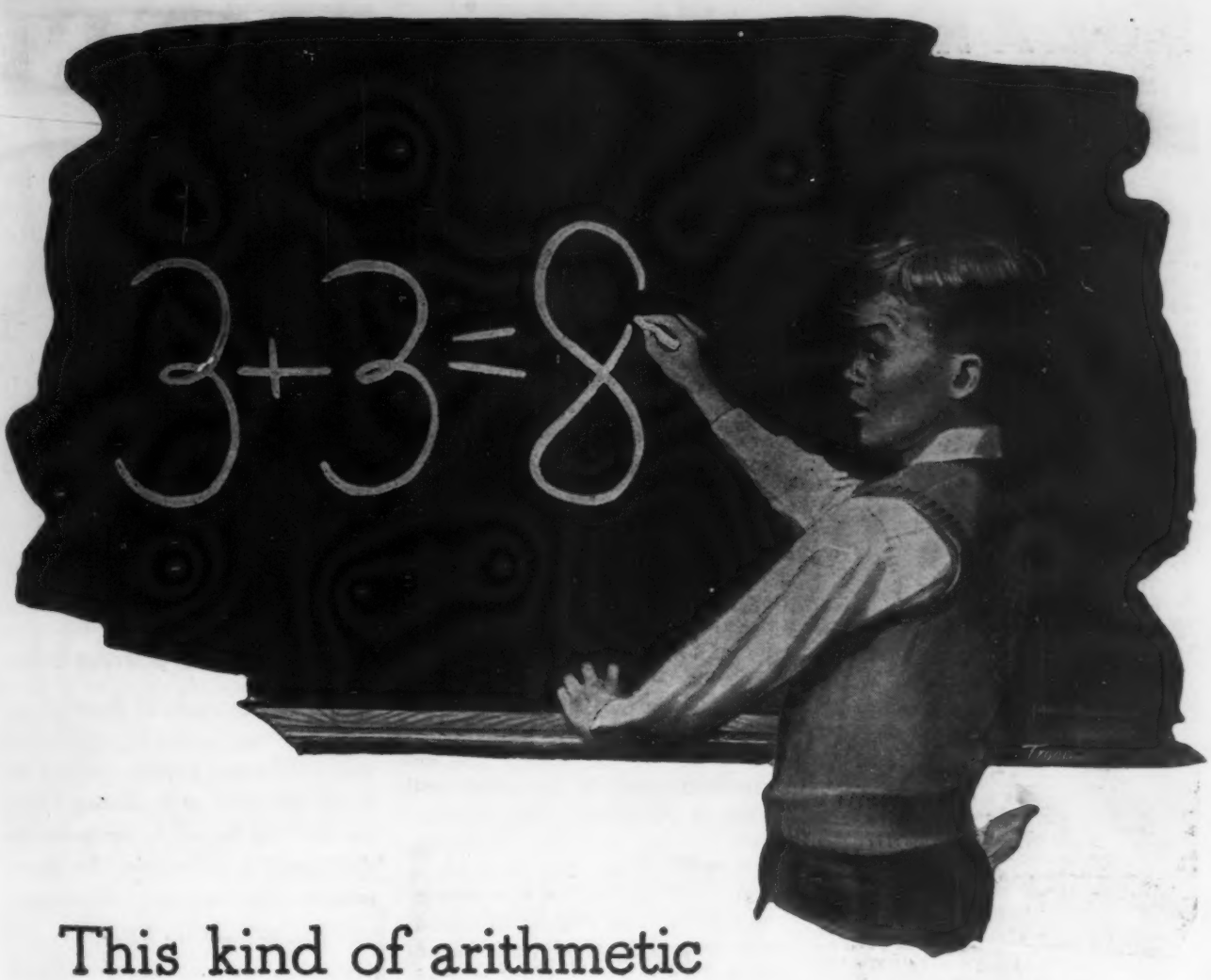

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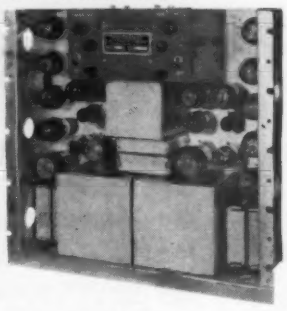

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Volume 1 of the MIT Radiation Laboratory Series, edited by LOUIS N. RIDENOUR *and written by 32 authors. McGraw-Hill Book Co., New York, 1947, 750 pages, $7.50.*

JUST as even in war it takes a long time to design and build radar sets, so even in peace it takes a long time to write and publish a technical book. The first volume of the history-making library known as the Radiation Laboratory Series is an example. So difficult is it to get things done today that a full year must elapse between the time a good-sized manuscript is received and the time printed copies are ready for readers. The editor's preface for this volume was written in June 1946; the book appeared in the middle of 1947.

The whole project for widely distributing the important facts and data developed during the life of the Radiation Laboratory has an interesting history, one which will never be published. The essential facts are that plans for the Series were made in the fall of 1944; a large staff of RL men was chosen to prepare the manuscripts and drawings, and actual work began about a year later. What started out to be a few books on microwave theory and techniques began to grow until material for 28 volumes was prepared. The concept of publishing this data, developed in deep secrecy, was bold and its execution was not without difficulty, what with security problems, ideas about government property and government expense and whatnot—not to leave out the vast investment to be made by the publishers.

But the essential fact remains that out of all the work carried out by thousands of scientists and engineers during the war, both in and out of the OSRD, only about 100 volumes will be published and of these less than 50 will be distributed so that their contents will be available. Except for the RL Series, a great bulk of the wartime developments in all branches of technology is locked up in the files, practically unobtainable; even the books—again excepting this radar library—will be difficult to see.

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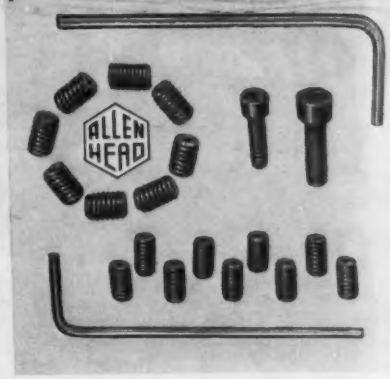

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therefore is a remarkable undertaking, in fact, a monument. Volume I deals, quite properly, with the broad radar picture, describing the components, the subassemblies, and the numerous radar systems. Although the subject matter is technical the editor of the volume is correct when he says in his preface "no special mathematical, physical, or engineering background is needed to read and understand this book," although it is barely possible that he has perpetrated one of the greatest understatements of the technical world when he says that "radar is a very simple subject."

The complexity of radar, the fascination of the things radar can do, the sidelights on its history and usage one finds in this volume, the truth that unbelievably complicated electronic circuits were developed complete and ready to go during the short life of the Radiation Laboratory—the fact that this book is interesting to read as well as worthwhile from the technical standpoint — all indicate that Volume I should rank high on engineers' purchase orders.

Only the chapter headings can be enumerated here—the radar equation, properties of radar targets, limitations of pulse radar, c-w radar systems, gathering and presentation of data, employment of radar data, radar beacons, antennas, scanners and stabilization, the magnetron and pulser, r-f components, radar receivers, indicators, power supplies, system design, moving target indication, radar relay.

The last two chapters present material hitherto unpublished. Here and there in this large book one gets glimpses of other items, paragraphs and chapters of radar history, and techniques and applications that are new to most and which will be useful as a technical storehouse for a long time.—K.H.

Alternating Currents

By CHESTER L. DAWES. *McGraw-Hill Book Co., Inc., New York, N. Y., 1947, Fourth Edition, 708 pages, $5.00.*

THIS fourth edition contains much new material, especially on electronic topics such as dynamic measurements, frequency modulation, selenium rectifiers, ignitrons, and electronic motor control.—J.M.

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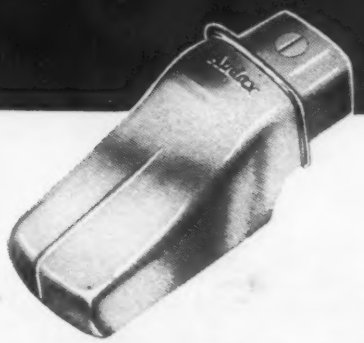

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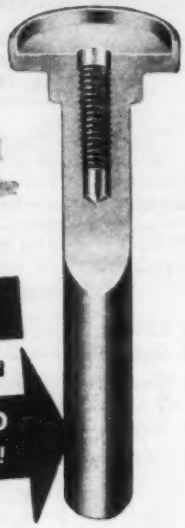

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Backtalk

This department is operated as an open forum where our readers may discuss problems of the electronics industry or comment upon articles which ELECTRONICS has published.

Triode Versus Pentode

Dear Editor:

ARTICLES published by ELECTRONICS in recent months indicate that at least a small group of engineers are aware that radio can, and should, bring the listener reasonably faithful reproduction of the speech or music transmitted. It seems timely to suggest that we "go ahead by going back"—back to triodes.

It has long been the contention of the writer that the tube manufacturers could, if they were gently prodded, produce a small triode capable of, say, two watts undistorted output, with little, if any, higher grid excitation necessary than is common to pentodes. To forestall possible comment, it should be noted that two watts of triode power, using a loud speaker load, actually means two watts of useful power, in contrast to the fraction of rated power that can be obtained from a pentode or beam tetrode without excessive distortion, at even moderately high frequencies.

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1. *Radar* includes systems em-

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X155M	8-8	450	39c	X160M	40	450	65c
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X157M	10-10	450	47c	X162M	16	500	39c
X158M	16	450	29c	X163M	100	50	15c
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ploying a radio frequency energy source transmitting in a preferred direction toward a *passive* object (target), which scatters the radiation incident upon it. A fraction of the scattered energy is then detected by a receiver, usually at the same location as the transmitter.

2. *Racon* (radar beacon) systems employ an interrogating transmitter, the signal from which is detected by a receiver at a second location. This signal, after suitable processing, then actuates a transmitter that replies with a signal bearing appropriate information (the answering signal need not employ the same wavelength as the interrogating signal). The answering signal is then detected by a receiver at location of interrogator. Examples are Oboe and Shoran.

3. *One-way navigational systems* employ a system of transmitters that establish a grid system in space for use by anyone having the necessary receiving equipment. Examples are Loran, Gee, and Decca.

Under this classification distinction is made between systems employing an echo from a passive target (radar) and those depending upon a triggered reply from a secondary system (racon); and finally the navigational systems involving transmission of energy in only one direction are considered to be separate. Obviously one type of system can perform part of the function of another; for instance, a radar system commonly provides a major fraction of the components at the interrogating end of a racon system. Also, radar systems function as navigational systems. This large degree of overlap does not alter the fact that there are two functions to be performed, and that there are some major differences in the manner of operation.

DONALD E. KERR
Massachusetts Institute of Technology
Cambridge, Massachusetts

THE EDITORS are informed that the word "Fathometer" is a copyrighted trademark of the Submarine Signal Company and was, accordingly, improperly used in the October 1947 issue of ELECTRONICS in the article "Telemetering Fathometer" since the equipment described was not manufactured by the Submarine Signal Company.

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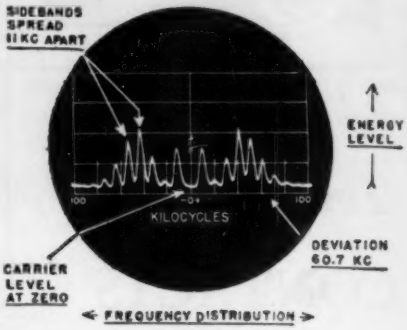
PANALYZOR

Eliminates tedious, time consuming point by point frequency checks. It shows simultaneously, in one complete picture, an FM'd carrier and resultant sidebands . . . in terms of relative frequency, amplitude and stability.



MODULATION= SYMMETRICAL

A single observation enables determination of such performance details as frequency deviation, energy distribution, sideband content, carrier shift and modulation symmetry . . . Operating procedures are simple . . . interpretations clear cut.

Actually, the PANALYZOR is a panoramic spectrum analyzor which shows, distributed in frequency, discrete quantities of r-f energy as vertical deflections on a cathode-ray tube.

Standard models now available with maximum scanning widths of 50 KC to 20 MC and corresponding resolutions of 2.5 KC to 100 KC.

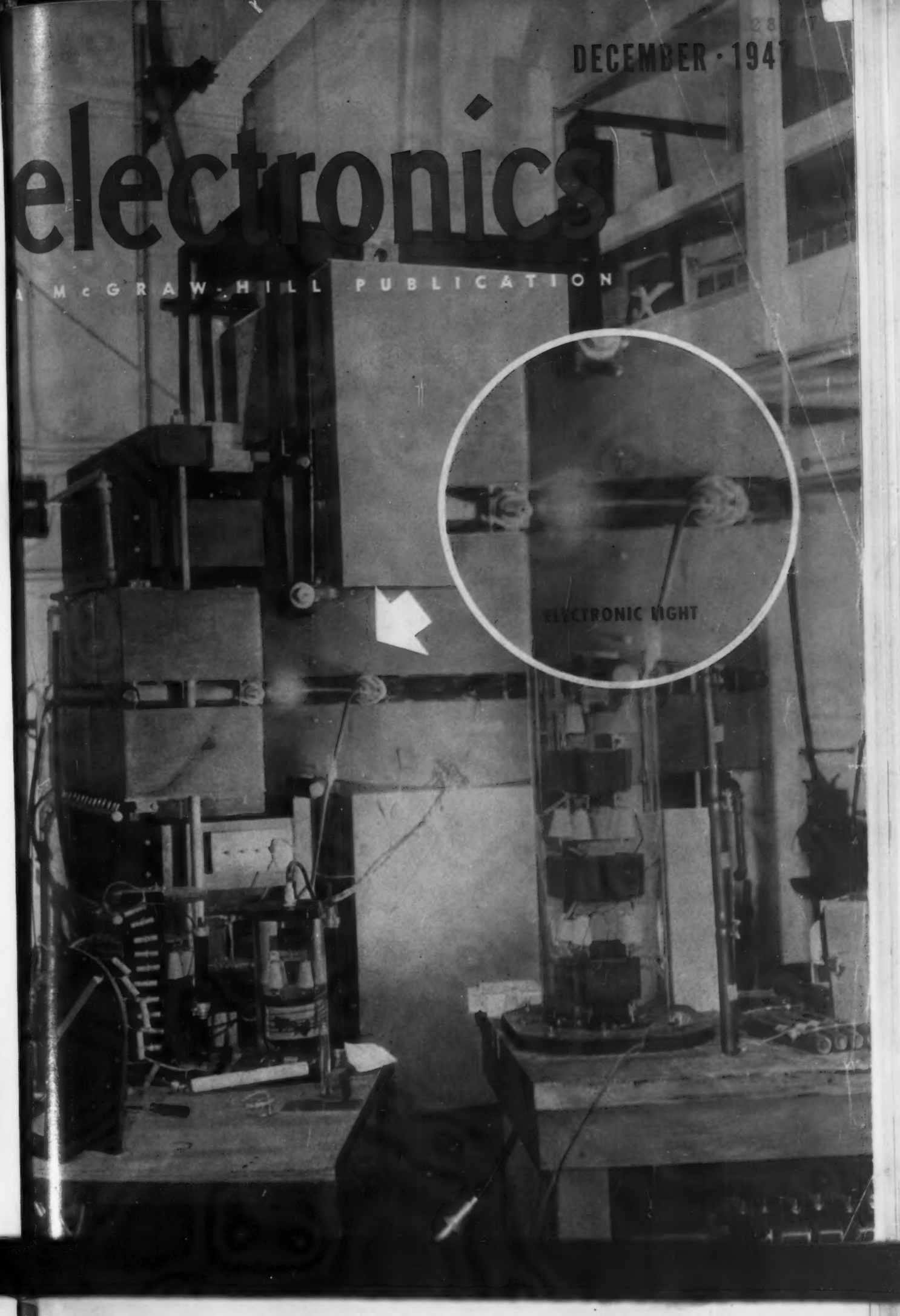
Write, wire or phone now for recommendations, specifications, prices and delivery time.

PANORAMIC RADIO CORPORATION
242-250 WEST 55TH ST. New York 19, N.Y.
Exclusive Canadian Representative: Canadian Marconi, Ltd.

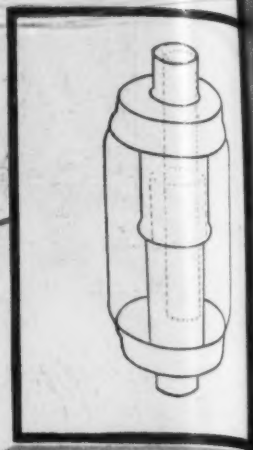
DECEMBER · 1941

electronics

A McGRAW-HILL PUBLICATION



the **LITTLE** differences make a **WHALE** of a difference



Jonah pulled a good trick when he got a round trip ticket into the whale . . . and we think we pulled a good one when we found a way of putting a heater inside our vacuum condensers to increase efficiency of our out-gassing.

Amperex vacuum condensers are tops because they are not only made of the simplest and best material for the purpose, pure, oxygen-free copper, but because we've succeeded in pulling a whale of a lot of gas out of the condenser by our trick. It takes heat to do it, and a condenser having no filament makes it quite a problem. But . . . by our design, another of those Amperex engineering differences, we can put heat right inside the vacuum condenser, right up against the elements where it does the most good. Of course we use standard out-gassing techniques, too, but we found that it's this Amperex difference that makes a whale of a difference to you, the direct heating of the elements that makes sure the last smidgeon of gas is pumped out.

Curious? The inside plate is tubular and open to the atmosphere. We drop a heater coil in there during pumping, cover the open end with a cap before finishing. (See sketch above)

We realize that such a design factor really can't be called a "little" difference, but there are hundreds of big and little differences in design and workmanship that really make a big difference in the many types of transmitting, rectifying and special purpose tubes that comprise the extensive Amperex line.

re-tube with Amperex

AMPEREX ELECTRONIC CORPORATION

AMPEREX

25 WASHINGTON STREET, BROOKLYN 1, N. Y.
In Canada and Newfoundland: Rogers Majestic Limited
11-19 Brentcliffe Road Leaside, Toronto, Ontario, Canada

Making Broadcast History!

NEW RING-SEAL POWER TUBES FOR FM AND TELEVISION

—110 to 220 mc frequency at max ratings

—1.5 to 6.4 kw typical Class C output

GENERAL ELECTRIC'S great 1947 series of ring-seal power tubes spells more efficient performance to those who build—or use—FM and television transmitters. Modern as tomorrow's telecast, these v-h-f tubes need minimum neutralization . . . are directly designed for grounded-grid circuits . . . meet in every way the *new* requirements of *new* station equipment going into service.

Ring-seal design — a G-E development—makes it possible to plug in a tube quickly, so that time off the air is cut to seconds. Firm terminal contacts with *wide surface areas* are another ring-seal advantage—moreover, all contacts are silver-plated to reduce r-f losses. An important aid to dependability and long life is the use, throughout the tube, of strong, enduring fernico metal-to-glass seals.

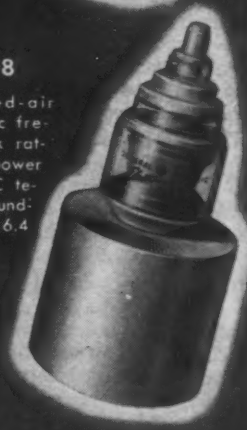
Your nearest G-E electronics office will be glad to give you prices and full information, as well as arrange for you to secure circuit application advice when desired. Or write direct to *Electronics Department, General Electric Company, Schenectady 5, N. Y.*

GL-7D21

Tetrode, forced-air cooled. 110 mc frequency at max ratings. Typical power output (Class C telegraphy) 1,575 w.

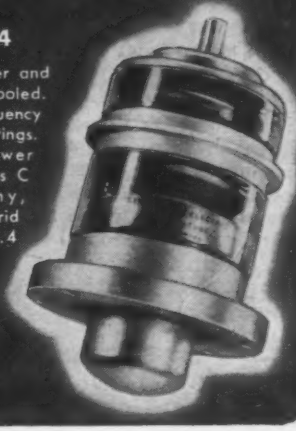
GL-5513

Triode, forced-air cooled. 220 mc frequency at max ratings. Typical power output (Class C telegraphy, grounded-grid service) 2.45 kw.



GL-5518

Triode, forced-air cooled. 110 mc frequency at max ratings. Typical power output (Class C telegraphy, grounded-grid service) 6.4 kw.



GL-9C24

Triode, water and forced-air cooled. 220 mc frequency at max ratings. Typical power output (Class C telegraphy, grounded-grid service) 6.4 kw.

G. E.'s MANUAL OF TRANSMITTING TUBES IS YOUR MOST COMPLETE, UP-TO-THE-MINUTE GUIDE!

Profusely illustrated—packed with performance and application data. Comes to you for $2. Also, for an annual service charge of $1 new and revised pages will be sent you regularly as issued. Order direct from General Electric Company, enclosing payment, or giving authority on your company letterhead to invoice you.

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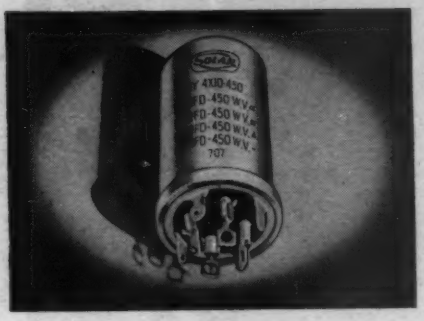
GENERAL ELECTRIC

161-FS-8850

FIRST AND GREATEST NAME IN ELECTRONICS

The Solar System
electronics edition · December 1947

TODAY'S TREND IS TO "TWIST-PRONG" ELECTROLYTICS



SET designers today are exhibiting a marked preference for Solar "Twist-Prong" dry electrolytic capacitors.

Tailored to modern set requirements of long life at high ambient temperature, high surge voltage, and low internal impedance, the advanced construction of Solar Type DY electrolytics ensures maximum performance at moderate cost in a modern electrolytic capacitor.

The rigid new mounting base of these capacitors, an exclusive Solar feature, stands up under vibration. The base vent is positive in action. The hermetic seal is positive and reliable.

The use of stable, high-gain etched foil gives not only superior electrical performance but makes for unusually small size. Special low-temperature electrolyte is used where set performance requirements dictate.

In conventional set designs, Type DY capacitors may be mounted above the chassis in holes punched through the chassis or on laminated phenolic or steel mounting plates, or they may be mounted horizontally below the chassis by means of spring-type mounting clips.

In the very latest set designs with plug-in component assemblies, Type DY capacitors are used in standard plug-in capacitor sockets.

Solar Type DY capacitors are available in an extremely wide range of capacitances and voltages. For further information, consult your nearest Solar representative, or write Solar Manufacturing Corporation, 1445 Hudson Blvd., North Bergen, N. J. Plants at Chicago, Ill.; North Bergen and Bayonne, N. J.

SOLAR CAPACITORS
"Quality Above All"

BUSINESS BRIEFS

By W. W. MacDONALD

Printed Circuits Symposium sparked by Bureau of Standards' Brunetti featured 20 speakers, attracted 700 electronic engineers and executives to Washington. Discussed were six methods[1-6] of achieving unitized wiring . . . *printing, spraying, dusting, stamping, chemical and vacuum* . . . and many manufacturing techniques in each of these categories.

Highlight impressions gained during the meeting include these: Many more manufacturers than most people realize are working on the problem. Widespread use of new wiring methods is largely dependent upon the speed with which suitable components can be developed, and this part of the program is just getting started. Actual military use of the idea is as yet limited to a few specialties such as the proximity fuse, but the Air boys are very much interested and even in the Army and Navy light, compact gear has many applications. Similarly, a hearing aid is the only commercially available device we know about at the moment that uses printed circuitry throughout, but several leading radio receiver makers are setting up pilot production lines so that they can check comparative costs.

Unitized wiring is destined to play an important part in our business. *But technical problems still to be solved will prevent it from revolutionizing the field overnight.*

(1) ELECTRONICS, p 104, April 1946.
(2) ELECTRONICS, p 194, May 1947.
(3) ELECTRONICS, p 82, June 1947.
(4) ELECTRONICS, p 158, July 1947
(5) ELECTRONICS, p 132, Sept. 1947.
(6) ELECTRONICS, p 106 (this issue).

Quotes: At the Printed Circuits Symposium an airforce representative said that what his branch of the service wanted in the way of electronic equipment was something that *"took no space, weighed nothing and did everything."* A manufacturer responded that what his company was trying to develop was a product that *"cost nothing and sold for something."* A third speaker injected the intriguing thought that when wiring equipment, we once *"started with the conductors and then put in insulation, and now start with the insulation and put in the conductors."*

Railroad Radio and inductive communications systems in use represent a substantial investment. Following is a partial list, compiled by the Association of American Railroads in October:

	*	
Atchison, Topeka & Santa Fe	R	$91,850
Baltimore and Ohio	R	7,635
Canadian Pacific	R	11,370
Chesapeake & Ohio	R	13,841
Chicago, Burlington & Quincy	R	46,720
Chi. Milwaukee, St. Paul & Pac.	R	34,778
Delaware, Lackawanna & Western	R	14,000
Denver & Rio Grande Western	R-I	109,524
Elgin, Joliet and Western	R	4,550
Florida East Coast	R	12,500
Great Northern	I	4,091
Jacksonville Terminal Co.	R	16,000
Kansas City Southern	I	63,900
Louisiana & Arkansas	I	8,600
Louisville & Nashville	I	3,756
Missouri-Kansas-Texas	R	13,500
Missouri Pacific	R-I	96,000
Pennsylvania	I	27,389
St. Louis-San Francisco	R	8,000
Terminal RR Ass'n of St. Louis	I	3,289
Union Pacific	R	20,645
Western Maryland	R	11,071

* R = radio, I = inductive.

Airborne Engine Analyzer developed by Sperry Gyroscope automatically narrows trouble down to a particular cylinder, and sometimes to a particular valve or sparkplug. Occasional misses are frequently shown up long before the pilot would otherwise be aware of impending failure.

We understand that faulty plugs account for about 50 percent of all engine troubles in the air and most delays on the ground, so the new electronic gimmick should save airlines much money and also improve schedules. One operator reports that it takes his mechanics an average of three hours to find faulty plugs without an analyzer, 30 minutes when one is available. The financial importance of time is emphasized by another, who says his big four-motored ships bring in $800 an hour in revenue.

Hotel Sound Survey by RCA just before the end of the war covered 108 buildings in the New York-Philadelphia area and several midwestern cities, indicated that all-year-round commercial types having 150 rooms or more (there are